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Pollution Effects of Abnormal Operations in Iron and Steel Making. Volume II Sintering, Manual of Practice

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16. ABSTRACT The report is one in a six-volume series considering abnormal operating conditions (AOCs) in the primary section (sintering, blast furnace ironmaking, open hearth, electric furnace, and basic oxygen steelmaking) of an integrated iron and steel plant. Pollution standards, generally based on controlling discharges during normal (steady-state) operation of a process and control system, are often exceeded during upsets in operation. Such periods of abnormal operation are becoming recognized as contributing to excess air emissions and water discharges. In general, an AOC includes process and control equipment startup and shutdown, substantial variations in operating practice and process variables, and outages for maintenance. The purpose of this volume, which covers the sintering process, is to alert those who deal with environmental problems on a day-to-day basis to the potential problems caused by AOCs, to assist in determining the extent of the problems in a specific plant, and to help evaluate efforts to reduce or eliminate the problems. The report enumerates as many AOCs as possible, with emphasis on those which have the most severe environmental impact. Descriptions include flow diagrams, material balances, operating procedures, and conditions representing typical process configurations.

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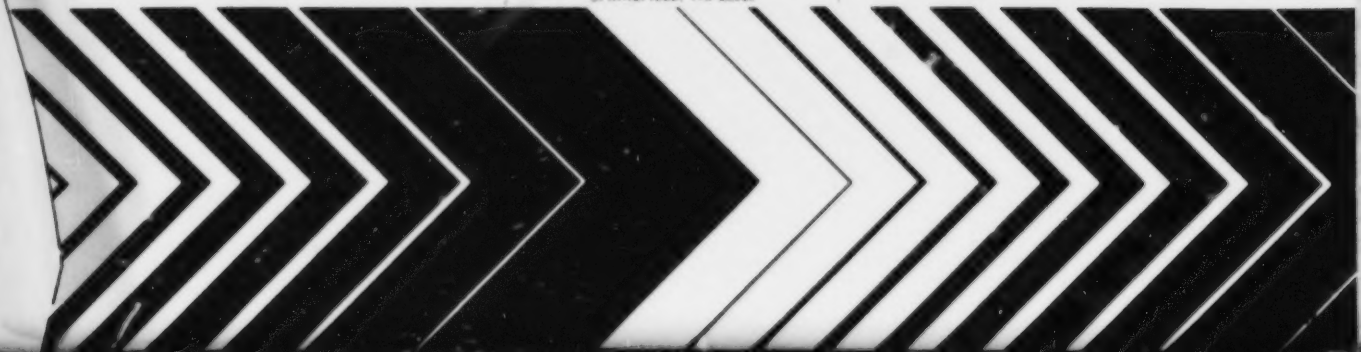

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by

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PREFACE

This study of the environmental effects of substandard, breakdown, or abnormal operation of steelmaking processes and their controls has been made to provide needed perspective concerning these factors and their relevance to attainment of pollution control. The use of the term Abnormal Operating Condition (AOC) herein, in characterizing any specific condition should not be construed to mean that any operator is not responsible under the Clean Air Act as amended for designing the systems to account for potential occurrence in order to comply with applicable State Implementation Plans or New Source Performance Standards.

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The project was carried out in RTI's Energy and Environmental Research Division under the general direction of Dr. J. J. Wortman. The work was accomplished by members of the Process Engineering Department's Industrial Process Studies Section, Dr. Forest O. Mixon, Jr., Department Manager, Mr. Ben H. Carpenter, Section Head.

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TABLE OF CONTENTS

	Page
LIST OF FIGURES	vi
LIST OF TABLES	vii
INTERNATIONAL SYSTEM OF UNITS AND ALTERNATIVE (METRIC) UNITS WITH CONVERSION FACTORS	viii
1.0 INTRODUCTION	1
1.1 Purpose and Scope	1
1.2 Definition of AOC	2
2.0 DISCUSSION OF THE SINTERING PROCESS, NORMAL OPERATION	3
2.1 Process Flow Sheet	3
2.2 Material Balance	3
2.3 Methods of Operation	5
Raw Materials Handling, Preliminary Mixing	5
Raw Materials Handling, Final Mixing	7
Emissions from Materials Handling	9
Sintering	9
Emissions from Sintering	12
Startup	15
Shutdown	19
3.0 CONTROL TECHNIQUES AND EQUIPMENT	21
3.1 Wastewater Pollutants	21
3.2 Emissions and Sources	23
3.3 Types of Controls Used	23
3.3.1 Windboxes	23
Electrostatic Precipitators (ESP's)	25
Fabric Filters	27
Scrubbers	31
Wet Electrostatic Precipitators (WESP'S)	36
Gravel Bed Filter	40
3.3.2 Product Handling	40
3.3.3 Materials Handling	42
3.3.4 Process Modification	42
4.0 ABNORMAL OPERATING CONDITIONS	44
4.1 Process Related AOC's	44

TABLE OF CONTENTS (cont'd)

		Page
4.1.1	Startup	44
4.1.2	Shutdown	45
4.1.3	Abnormal Operating Conditions	45
	Product Handling	49
4.2	Control Equipment Related AOC's	50
4.2.1	Startup	50
	Precipitators	50
	Warmup	50
	Stack Puff	52
	Unbalanced Flow Among Manifolded Fans	52
	Insufficient Draft, Fan Malfunctions	53
	Fabric Filters	54
	Scrubbers	55
4.2.2	Shutdown	55
	Precipitators	55
	Baghouses	55
	Scrubbers	55
4.2.3	Abnormal Operation	55
	Downtime of Control Systems	55
	Precipitators	57
	Downtime of Secondary Systems	57
	Rapping	58
	Rapper Failure	58
	Wire Breakage	59
	Dust Removal System Breakdown	62
	Sprays Plugged or Corroded	63
	Transformer-Rectifier Set Failure	63
	Insulator Failures	64
	ESP Maintenance	65
	Fabric Filters	65
	Baghouse Maintenance	66
	Scrubbers	66
	Sprays Corroded or Plugged	69
	Plugged or Corroded Pipes	70
	Corroded Pump Impellers, Pump Failure	71
	Plugged or Failed Demister	71
	Drum Filter Failure	72
	Acid Cleaning Scrubber Components	73
	Control Process Modifications	73
5.0	TABULATED SUMMARY OF AOC	74
6.0	REFERENCES	84

LIST OF FIGURES

		Page
1.	Typical sinter plant flow diagram for superfluxed sinter	4
2.	Typical material balance for superfluxed sinter from a modern sinter plant	6
3.	Typical duct electrostatic precipitator	25
4.	Schematic diagram showing flow and controls for a sinter plant baghouse	29
5.	Recycle plant, Middletown Works scrubber system flow diagram	32
6.	Scrubber plant, Houston Works, scrubber system flow diagram	35
7.	Mikropul pilot WESP test setup at a sinter plant	37
8.	Full scale WESP demonstration at a sinter plant	38

LIST OF TABLES

		Page
3-1.	Uncontrolled Scrubber Water Pollutants From a Sinter Plant and Estimated Control Required	22
3-2.	Uncontrolled Pollutant Emissions from Sinter Plants and Estimated Control Required	24
5-1.	Sinter Plant Abnormal Operating Conditions	75

INTERNATIONAL SYSTEM OF UNITS AND ALTERNATIVE (METRIC) UNITS
WITH CONVERSION FACTORS

Quantity	SI Unit/Modified SI Unit	Equivalent To
mass	kg	2.205 lb
	Mg (megagram = 10^6 grams)	2205 lb
	Mg	1.1025 ton
	Gg (gigagram = 10^9 grams)	
volume	m^3 (cubic meter)	35.32 cf
	dscm (dry standard cubic meter)	
	scm (standard cubic meter: 21°C, 1 atm)	
	ℓ (liter = 0.001 m^3)	
concentration or rate	g/m^3 (grams/m^3)	0.437 gr/ft^3
	mg/m^3 (milligrams/m^3)	0.000437 gr/ft^3
	g/kg	2 lb/ton
energy	J (joule)	0.000948 Btu
	kJ/m^3 (kilojoules/m^3)	0.02684 Btu/ft^3
	MJ (megajoules = 10^6 joules)	
	MJ/Mg	0.430 Btu/lb
		859 Btu/ton
force	kPa (kiloPascal)	0.146 lb/in^2
	1 Pascal = 1 N/m^2 (Newton/m^2)	
area	m^2 (square meter)	10.76 ft^2

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

Air and water pollution standards, generally based upon control of discharges during normal (steady-state) operation of a control system, are frequently exceeded during "upsets" in operation. When such upsets become repetitive and frequent, the regional and local enforcement agencies undertake, through consent agreements, to work with the plant toward resolution of the problem, and plans are developed for such equipment and operating practice changes as will eliminate or alleviate the frequent violations. Should the planning process fail to resolve abnormally frequent occurrences of abnormal operating conditions, the problem may lead to litigation. Thus, periods of abnormal operation are becoming recognized as possibly contributing to the emission of high concentration of pollutants. Similarly, upsets may contribute to spills of increased amounts of effluent-borne pollutants into waterways.

There is a need for information concerning abnormal operating conditions (AOC): their identity, cause, resulting discharges, prevention, and minimization.

The purpose of the manual is to alert those who deal with environmental problems on a day-to-day basis to the potential problem areas caused by abnormal conditions, to assist in determining the extent of the problem created by abnormal conditions in a specific plant, and to provide help in evaluating any efforts to reduce or eliminate the problems. The processes considered are those in the primary section of the integrated iron and steel plant. Included are the sintering, blast furnace ironmaking, open hearth, electric furnace, and basic oxygen steelmaking. This manual covers the sintering process.

This manual is based on reviews of somewhat limited data, visits to a few of the many steel plants, interviews with persons intimately involved in either steelmaking or attendant environmental regulations, and the expertise of the study team. It is, therefore, a preliminary assessment which concentrates on enumerating as many of the conditions as possible, with emphasis on those which have the most severe environmental impact.

Each process is described separately. Descriptions include flow diagrams and material balances, operating procedures and conditions. The flow sheets and material balances presented are representative of the most typical process configurations.

Within each process are variations, both in the process itself and in the equipment for control of pollution. Variations in equipment and process are accompanied by variations in AOC. It is, therefore, of value to identify as many of the variations as possible. At the same time, it is necessary to limit consideration of the numerous alternatives to those which are currently in greatest application and use.

1.2 DEFINITION OF AOC

In general, an abnormal operating condition (AOC) is considered to be that which departs from normal, characteristic or steady-state operation, and results in increased emissions or discharges. In addition to abnormal operations, this study includes startup and shut down difficulties of processes and control equipment. It also includes substantial variations in operating practice and process variables, and outages for maintenance, either scheduled or unscheduled.

The use of the term Abnormal Operating Condition (AOC) in characterizing any specific condition should not be construed to mean that any operator is not responsible under the Clean Air Act as amended for designing the systems to account for potential occurrence in order to comply with applicable State Implementation Plans or New Source Performance Standards.

2.0 DISCUSSION OF THE SINTERING PROCESS, NORMAL OPERATION

The primary function of sintering is to agglomerate dusts and sludges from pollution control sources and fine ores into lumps suitable for charging into the blast furnace. The secondary function of sintering is to provide part or all of the flux material for the ironmaking process.

The primary function stems from the need to provide physical mass, size, and strength to the material. Fine particles, if charged into the blast furnace, will be blown out by the rapid countercurrent flow of the furnace gases. Lumps, being physically larger, will not be so affected.

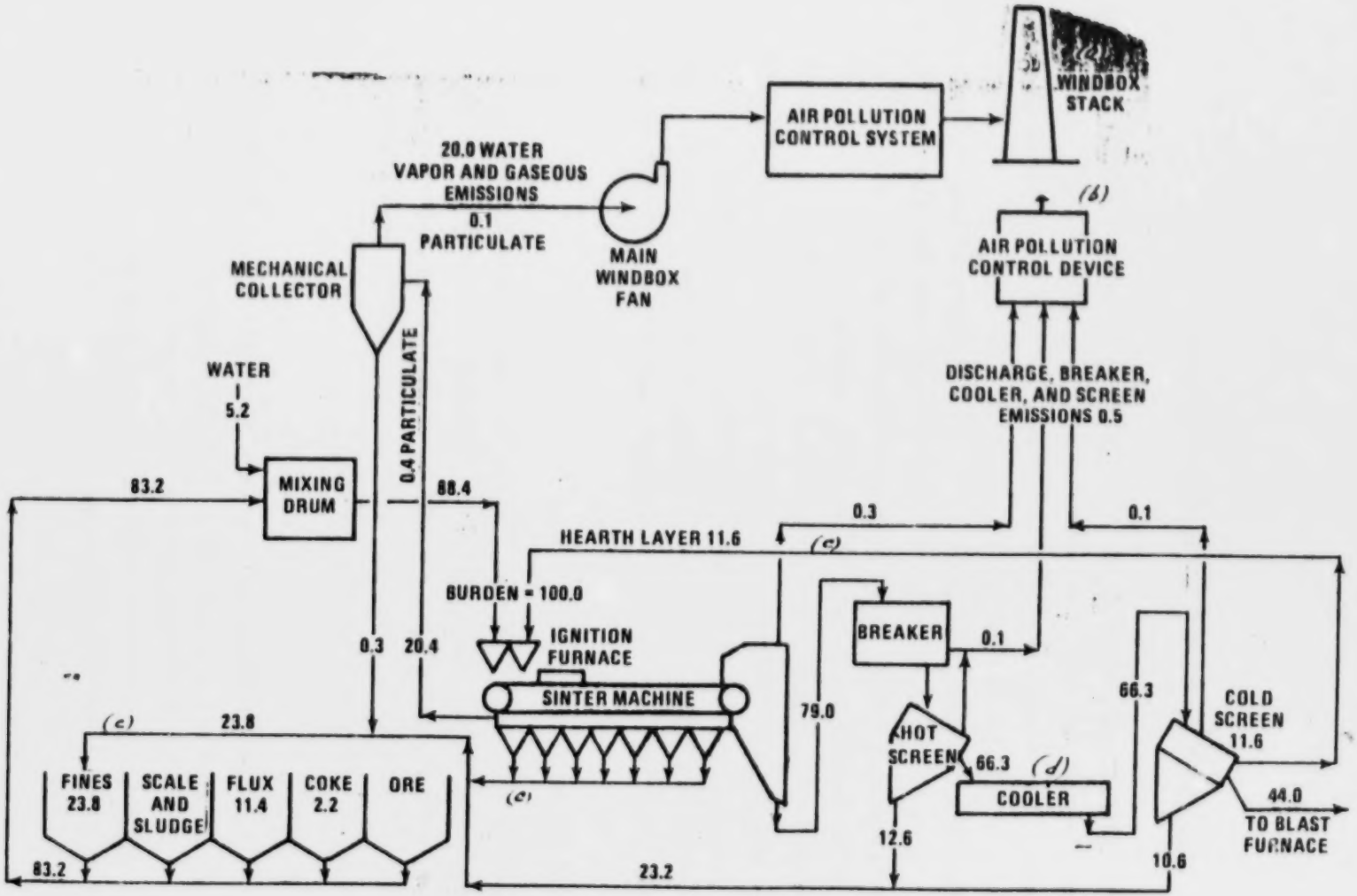
The secondary function stems from the economics of the ironmaking process. A blast furnace operates more economically if the flux is pre-calcined, that is if lime (CaO) is charged rather than limestone ($CaCO_3$). It is, however, too expensive to substitute purchased lime for limestone in the blast furnace. The preferred course is to mix limestone in the sinter feed and use the heat of the sintering process for calcining it.

2.1 PROCESS FLOW SHEET

The sintering process, as described herein, includes receiving, mixing, feeding, and agglomerating the raw materials; the actual sintering operation; and the crushing, screening, cooling, and transferring of the sinter product. A flow sheet for the process is shown in Figure 1. The letters in brackets ( ) indicate the areas of greatest potential for AOC.

2.2 MATERIAL BALANCE

Feed material to the sintering process includes primarily ore fines, and also reverts (blast furnace dust, mill scale, and other byproducts of steelmaking) recycled hot and cold fines from the sintering process and trim materials (calcite fines, and other supplemental materials needed to produce a sinter product with prescribed chemistry and tonnage). Generally, some 2.5 tons of



[a]PROCESS THROUGHPUTS DO NOT INCLUDE AIR.

Figure 1. Typical sinter plant flow diagram for superfluxed sinter.

strand burden, including water and fuel, are fed per ton of sinter produced, and about 2832 standard cubic meters (scm) of pollutant-containing air must be cleaned.

Figure 2 shows a material balance for a typical sinter plant making superfluxed sinter.

Variations in the material balance may result from the following factors:

1. The amount of return fines may increase (or decrease) if the quality of sinter degrades (or improves), or if the efficiency of screening improves (or reduces).
2. The use of a hearth layer is optional. Although it is a preferred technique, some older plants do not have the necessary equipment for creating the hearth layer.
3. The amount of flux material varies from plant to plant depending on the percentage of sinter used in the blast furnace burden, the flux requirements of the blast furnace, and other production factors in the ironmaking complex. In general, economics favor the high flux, or superflux sinter.

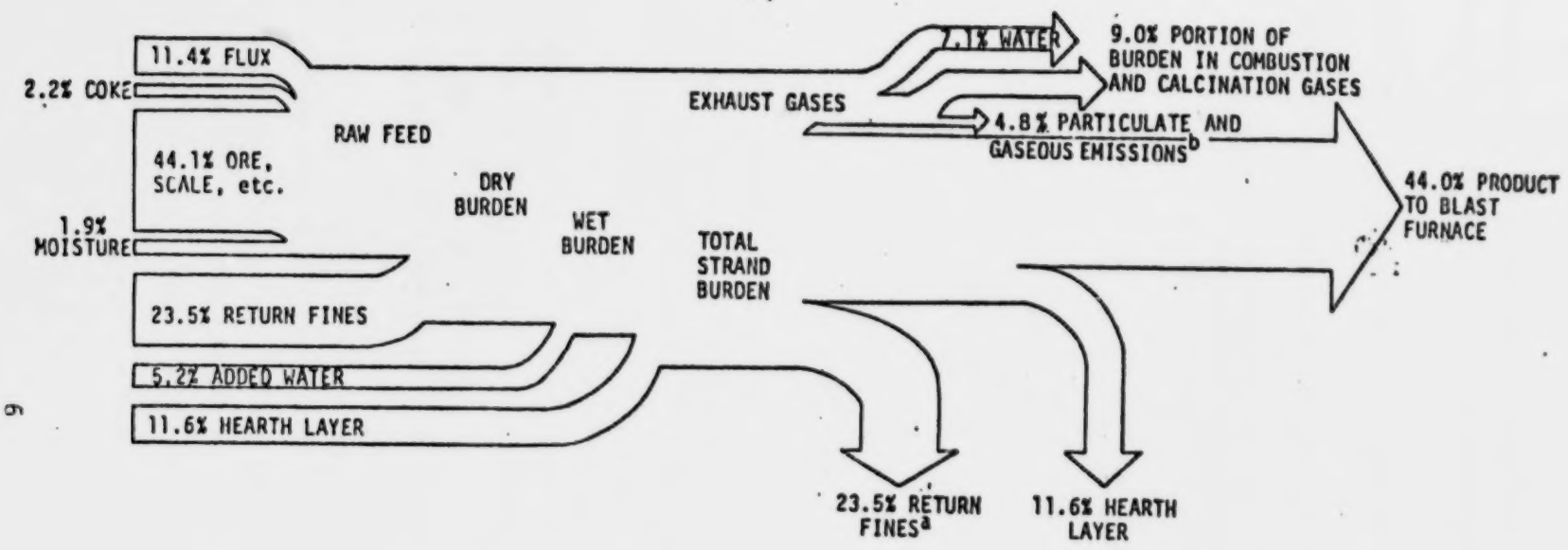
2.3 METHODS OF OPERATION

Raw Materials Handling, Preliminary Mixing

Consistent and accurate proportioning of sinter strand feed materials followed by thorough mixing is necessary if a uniform product of desired quality is to be obtained. Preliminary blending of a portion of the feed may be done either using a bedding system or a conveyor belt system.

A bedded pile constructed at the bedding plant may consist of some 45.4 Gg (50,000 tons), in which revert materials may account for 40 percent of the total quantity. The pile can be constructed over a period of about five operating days. It is constructed longitudinally with up to 500 layers stacked as prescribed by the blending scheme. It is reclaimed cross-sectionally to provide a raw-mix feed to the sinter plant.

The materials are proportioned and mixed in order to prepare a chemically uniform feed to the sinter strand, with a composition prescribed so that the sinter resulting will have qualities desired for satisfactory blast furnace operation. The chemical quality of the sinter is often assessed in terms of its basicity (B/A), the percent total basic oxides divided by the percent total acid oxides:



[a]Includes fines from cooling, screening, and transfer points also.

[b]Includes particulate emissions from cooling, screening, and transfer points also.

Figure 2. Typical material balance for superfluxed sinter from a modern sinter plant.

$$B/A = (\%CaO + \%MgO)/(\%SiO_2 + \%Al_2O_3)$$

The basicity each material to be blended is often utilized, along with time and quantity constraints, to obtain a preparation schedule for the bedded pile. A more meaningful chemical quality criterion for blending calculations is the stone equivalent (SE) defined as the pounds of stone available for fluxing per 100 kilograms (220 lbs) of material:

$$SE = 100\,\frac{(\%CaO + \%MgO)_m - B/S((\%SiO_2)_m - 2.14\,(\%Si)_{hm}(\%Fe)_m/(\%Fe)_{hm}))}{((\%CaO + \%MgO)_s - B/S((\%SiO_2)_s - 2.14\,(\%Si)_{hm}(\%Fe)_s/(\%Fe)_{hm}))}$$

where m = material to be blended

s = the stone being charged to the blast furnace

hm = the blast furnace hot metal

2.14 converts Si to SiO_2, and

B/S = the base to silica ratio of the blast furnace slag: $(\%CaO + \%MgO)/(\%SiO_2)$.

Using Direct Digital Computer control of the mixing process, to convert the analyses of each material to stone equivalents, develop a schedule for the bedded pile (required tonnages, feed rates, and time schedules for refilling storage bins), one new bedding plant met its target stone equivalent value of 12.0 with a standard deviation of 0.7 over a one quarter year period. Most current mixing operations would not be expected to attain such uniformity.

Raw Materials Handling, Final Mixing

Material from preliminary mixing goes to feed bins at the sinter plant. Other feed bins there hold fluxing materials, coke breeze or coal fines and sinter fines. These materials are proportioned onto a conveyor belt, preferably by separate variable feed rate weigh belt feeders. The relative amounts of each material are determined by calculation, considering the desired B/A or SE value, the rate of consumption of material at the sinter strand, the amount of sinter fines that must be recycled, and the total carbon content needed for proper ignition and sintering.

Water is added as the material conveyed from the feed bins reaches a pug mill or balling drum where it is pelletized (rice-sized pellets) and fed to the roll feeder surge hopper. The surge hopper can serve to uncouple, momentarily, the rate of strand burden production from the sinter strand feed rate. The surge hopper level is monitored and fed back manually or automatically to control the feed bins discharge rates.

BOP dusts, if returned to the sinter plant, require special handling to control fugitive emissions.

The successful transport of BOP flue dust to the sinter plant has been reported using (1) center flow hopper cars to haul the dust to the plant, (2) 14" screw conveyors to unload the cars, (3) 18" belt conveyors to the feed chute which discharged directly onto the sinter mix gathering conveyor. Baffles were hung inside the gathering conveyor cover and steam was introduced inside the last drop point. The steam cloud moved, back under the enclosed cnveyors and effectively dedusted the system. This dust contained calcined lime (CaO and Mg). Prior to adoption of this system, the dust cake after treatment with water sprays and clogged a verticlone feeder. Mixing the dust with blast furnace thickener sludge proved not to be satisfactory.

Rounds and Germinder report that mixing BOF dust with wet mill scale mitigates the fugitive dust problem.[8] Ostrowski and Hass report the successful pilot testing of a vertical mixer to blend mill scale, BOP dust, blast furnace flue dust, and blast furnace sludge.[3] Sludge was fed from a ribbon feeder and flue dust, BOP dust, and mill scale from bins onto a common collector belt leading to the mixer. Water was added, using conventional spray nozzles, onto the conveyed mix upstream and downstream of the BOP dust feed bin. The final blend was fed onto the sinter mix conveyor belt from conventional storage bins using the conventional table-type feeder. While no increase in dust loading of the waste gas stack were observed while consuming the blended BOP dust, the zinc content of the particulate matter increased. A zinc balance, made during the tests, showed a 22-26 percent loss, potentially to the environment.

Emissions From Materials Handling

Fugitive dusts are predominant emissions from raw material handling. While such dusts are evident in nearly every plant, exhausts from building ventilation are not usually visible unless fine dusts such as BOF flue dust are handled with conventional miscellaneous material systems. Pugh and Fletcher reported 60 percent loss of this dust in transfer and transport by uncovered conveyors.[1]

Sintering

The sintering machine accepts feed material from the roll feeder surge hopper, and conveys it down the length of the moving strand. On the way, the fuel in the mix is ignited, then burned using an induced draft. The heat (some 174 MJ per Mg of product (150,000 BTU per ton) agglomerates the fine particles forming a cake of porous clinker. The cake is discharged from the sinter strand to a breaker which reduces it to pieces up to six inches in size. In modern sinter plants, the crushed product is screened before and/or after cooling; in older plants one or both steps of screening may be absent. Fines and, usually, pieces suitable for use as a hearth layer are returned to the feed system. The sinter product is transported to feed areas for the blast furnace.

The sinter machine strand is composed of pallets (small cars) which ride on rails over the windboxes. Each pallet has a grated bottom, open ends where the cars come together and sideboards of maximum height for the sinter bed. The active surfaces on sinter machines are up to 4 meters wide and 61 meters long. Material is fed to a depth of up to 40 cm.[2] Grate speed can range from 15 to 3 meters per minute. At the discharge end of the machine, the cars pass down and return upside down as would a normal conveyor.

The windboxes (compartments under the bed) provide for a controlled distribution of combustion air as it is drawn through the sinter bed. Air is drawn down through the burden, into the windboxes and through an initial separator to a large fan. Very coarse particulates (up to 1 cm diameter) are recovered in the windboxes. Other somewhat less coarse particulates are removed by the separator. Over 14,000 m^3/min (500,000 cfm) of air at about 190°C may be drawn

through the burden at a static pressure of 120 cm (40 inches) of water gauge. (Fans are typically designed to draw 935 to 1029 scm (30,000 to 33,000 scfm) per net Mg (ton) of raw material on the strand.) After the fan the gases are subject to further cleaning and possibly recirculation before discharge to the air.

The discharge end has a separate ventilation system for the crusher and hot screens, with a gas volume of some 1.65 scm/min (50 scfm) per Mg per day of sinter. These gases are subjected to cleaning before discharge to the air.

Sinter coolers are most commonly either quiescent, circular, or straight line moving beds (with forced or induced draft). A portion of the cooling air may be fed to the windbox system to utilize its heat content.

The sintering process operates normally under controls which maintain conditions set to achieve the desired product, with further controls to sense and adjust for irregularities in materials flow and system breakdown.[3,4] Interlocking switches are used to insure that subsystems are started and stopped in prescribed sequence. The subsystems themselves are interlocked so that for example, if the product conveyors failed, the entire system (burden-sinter-and-product groups) would shut down until the trouble is corrected.[3]

Typically, six categories of control (control loops) are applied by the operators or by computers under their direction.

1. Control loop 1 sets and maintains the material discharge rates from the feed bins. The rates themselves are calculated to meet four constraints. The stone equivalent of the sinter after combustion, must be equal to a prescribed value. The total amount of feed material discharged onto the main conveyor must equal the amount being consumed by the sinter machine, modulated upward or downward by the current material level in the roll feed surge hopper. The total amount of material being discharged from feed bins must include a specified percentage of sinter fines. The total carbon content in the feed material must meet a specified setpoint percentage.

2. Control loop 2 monitors the material level in the roll feeder sunge hopper and reacts thereto. If the level becomes extremely high, the entire feed line is stopped until the conditions is corrected. Less extreme variations in the level will actuate proportionate adjustment of all bin feed rates.

3. Control loop 3 controls water addition to the raw sinter mix. Water is added just prior to the mixing (balling) unit to promote balling of the fine material. While water may be added directly proportioned to the mass flow of material, further control is often applied based on measuring the actual moisture in the raw mix at the discharge of the balling unit and comparing with the moisture setpoint.

4. Control loop 4 regulates the speed of the roll feeder (or alternate) which regulates the discharge of balled sinter mix onto the loading station of the moving grate sinter strand. Proper loading occurs when sufficient material is maintained at the loading station to generate a wave of material wiped from the top surface of the raw mix bed behind the strike-off plate. Probes sense the existence and extent of material at this point, and actuate adjustments to match the discharge rate of the feeder to the volumetric consumption rate of the strand. Several changes can be made to achieve the match. The feeder may be slowed down relative to the sinter strand feed, the strand may be speeded up ten percent until the probes are cleared of excess material, or the entire feed line may be stopped momentarily.*

5. Control loop 5 regulates the speed of the strand's traveling grates based upon the rate of combustion of the fuel in the feed mix. The combustion is supported by suction produced below the strand by an induced draft fan system, so that the heat and combustion products are drawn down through the bed. Conventional practice aims to have the vertical combustion burn through as the grate pallet has just traversed the length of the strand. The burn-through point is detected by monitoring the induced draft gas temperatures in the windbox segments throughout the length of the strand. The resulting temperature profile is evaluated yielding a calculated burn-through point. This point is compared with the prescribed location, and the strand speed is adjusted to minimize the difference. The sinter draft fan is controlled to maintain a preset suction ($-\Delta P$) in the windboxes. A pressure sensor signals changes in the fan damper subject to limits on the fan motor load current.

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*Speeding up the sinter strand may be the least desirable change from the standpoint of emissions control.

6. Control loop 6 matches the speed of the sinter cooler. These rates are usually uncoupled by a small-capacity surge chute at the cooler loading station. Using the level of hot sinter in the chute for control, it maybe sensed by a nuclear level detector, with attendant modulation of the cooler speed to keep sufficient material available so that bed voids will not occur on the cooler, and to prevent chute overfill.

A breakdown in the product cooler system (which includes cooling, screening, fines return, and product storage operations), will shut down the whole producing plant pending corrective action.

Emissions from Sintering

Emissions from sintering occur in the windbox exhaust gases, in the sinter product handling ventilation gases, and as fugitive emissions. Windbox emissions consist of filterable and condensible particulates, hydrocarbons, SO_x, CO, NO_x, and, possibly, fluorides. Uncontrolled filterable particulate concentrations in windbox exhausts before the mechanical collectors have been shown by tests to be 4.6 - 9.2 g/scm. Genton gives the following typical particle size analysis:[5]

Size, microns	Percent by weight
100 and over	7.6
100 - 80	1.3
80 - 60	0.9
60 - 40	4.0
40 - 20	17.5
20 - 10	41.3
10 - 1	27.4

Windbox particulate emissions are influenced by particle size distribution, burden composition, bed air flow rate, sinter machine design, and operating techniques.

Some operating techniques which affect windbox particulate emissions are:

1. Very fine materials in the burden, such as dust from the BOF operation, may result in an increase in the amount of particulate emitted as well as in its fineness.

2. Improper proportioning or mixing of the raw feed may result in non-uniform sintering. Some of the feed may not become sintered and may be drawn through the grate bars.

3. Improper maintenance of grate bars may allow a portion of the raw feed to fall through the grates thereby increasing the amount of transported particulates. The holes in the bed of feed material which result also increase the volume of gas to be handled by the pollution control device. This will increase emissions to the atmosphere by virtue of the increased mass of particulates carried out with the increased flow of gas and compounded by the increased concentration of particulates in the gas. The increase in concentration together with the increased flow intensifies the adverse environmental effect of the leakage.

4. Improper maintenance of machine seals increases gas flow, resulting in increased emissions. The same results from unpatched holes in windboxes and ducts, improperly operating dust valves, etc. Minimal emissions are directly related to minimal air flow. To achieve minimal air flow when handling highly abrasive sinter dust requires constant vigilence and effort on the part of operating and maintenance personnel.

5. A hearth layer, if used, serves the dual function of protecting the grate bars from heat, thereby prolonging their life, and helping to keep feed material from passing into the windboxes, thus decreasing the concentration of emissions carried into the gas.

Visible plumes due to particulates are usually reddish while hydrocarbon emissions are bluish. Sulfur oxides emissions depend on the sulfur content of the iron-bearing material and the amounts of coke, ignition fuel, and limestone used. Average emissions (12 U. S. plants) were found to be 112 ppmv, equivalent to about 0.9 g SO_2 per kg of sinter (1.8 lb/ton).[6]

About one fourth of the carbon fed is burnt to carbon monoxide (CO), and the rest to CO_2.[7] Emission rates will depend on the coke content of the sinter burden and the completeness of combustion but run about 12 g/kg of feed, or 28 g/kg of sinter produced (24 lb/ton of feed, or 56 lb/ton of sinter produced).

Source tests show about 70 ppmv NO_x (equivalent to 0.3 g NO_x/kg (0.6 lb/ton) of strand feed or 0.7 g/kg (1.4 lb/ton) of sinter).

In a sinter plant with a well-operating scrubber of medium differential pressure (75 to 100 cm of water) or a well-operating dry precipitator of adequate size, one of the chief causes of excess opacity is the presence of these vaporized hydrocarbons. Neither of these control units are particularly efficient in capturing these vapors. If the control device is a baghouse, the presence of hydrocarbon vapors is particularly detrimental because the vapors contribute to the blinding of the bags and add a considerable fire hazard.

Hydrocarbon vapors in a sinter plant generally originate from oil in the feed material. Some sources of oil-bearing feed are:

1. Mill scale which absorbs oil that finds its way into mill water from leaky bearings, hydraulic equipment, etc.
2. Blast furnace sludge which absorbs oil that finds its way into blast furnace scrubber water from the blast furnace process itself.
3. Coke breeze which may contain tarry material and which absorbs oil from the water in the sump of the quench tower.

If the oil-bearing feed material is not uniformly distributed through the total feed burden, there may be occasions where the concentration of these materials becomes much higher than normal. Under such conditions, the concentration of hydrocarbon vapors in the stack may be expected to increase and give rise to increased opacity. The oil present in the feed material appears to be vaporized on the strand ahead of the flame front and pyrolyzed.[8] Measured emission rates have averaged 1.0 gm/kg of strand feed (2.3 gm/kg of sinter product), expressed as methane (2 lb/ton and 5.6 lb/ton respectively).

Ore fines are the source of fluorides, reported to run as high as 150 ppmv.[2] Source tests show a range of 2 - 15 ppmv following mechanical collectors (0.004 to 0.025 g/kg of strand feed; 0.008 to 0.050 lb/ton).

Odorous substances may be emitted if significant quantities of mill scale, filter cake, or other oily scrap materials are used, but odor problems were identified only once during plant visits conducted for this study.

Particulate matter from the sinter breaker and product handling operations will depend somewhat on the completeness of sintering. Uncontrolled particulates have been estimated at 11 g/kg of sinter product.[5] (The joint EPA-AISI estimate is 14 g/kg or 28 lb/ton.) Hernick has reported uncontrolled dust concentrations of 7 - 18 g/scm (3-8 gr/scf).[2] If screens and conveyor transfer points are not hooded, dense visible emissions may occur. If water sprays are used, steam and mist will be generated.

Startup

Startup procedures vary from plant to plant as to sequence, depending upon the nature of the interlocking controls and the relative importance assigned to the different systems. Best practice with respect to control of emissions appears to be that which starts up the emissions controls the earliest. The following startup sequence was selected from among those compared to represent better current practice.

1. A roll of paper is used to cover the empty strand. The paper is removed as it reaches the discharge end of the machine.
2. Start sinter cooler fans.
3. Start hearth layer group (interlocked conveyors and controls) if a hearth layer is used.
4. Start dust group, which conveys collected dust from the windboxes and emissions controls and returns it to the feed system.
5. Start windbox control unit.
   a. Control by ESP -- If the control is an ESP, its power unit will likely be permissive from its attendant dust conveyors, that is, the conveyors must be running before the power unit can be started. After startup, the permissive interlock is bypassed and the ESP continues to run until shut down by its own stopping devices.

      After start of the dust conveyor system, determine that air (414 kPa, 60 psig) is available for rapper controls; provide power to the rapper control panel; turn on suspension insulator electric heaters; determine that all grounding switches are properly set and all doors closed and locked; admit air to the precipitator; allow 60 minutes warmup to drive off any condensed

moisture from the insulators; put ESP power supply into operation; after about one minute to warmup tube filaments, apply plate voltage; review readings of current and voltage to the primary of the high voltage step-up transformer and the voltage drop across the power saturable reactor; review power output as shown by control potentiometer.

Note: Admitting air to the ESP involves startup of the windbox fan. The load on this fan is regulated by a hydraulic-electrical mechanism (e.g., an Askania regulator) which adjusts the fan inlet damper between the limits of fully closed and fully open. The regulator will function to maintain a manually set inlet suction pressure cotrol point (within the load limit of the fan driving motor). When the main draft fan is stopped, the regulator automatically closes the inlet damper. To start the fan, the regulator hydraulic pumping unit must be started first. If the regulator is shut off, it should automatically drive the fan damper to the closed portion before the hydraulic pump unit shuts itself down. The pumping unit cannot be shut down while the fan is running; if the unit shuts down on overload, it also shuts down the fan.

After the regulator is started, the draft fan is started using the following steps: turn on the excitation power supply (normal or emergency) for the motor field; actuate high voltage switch gear unit switches; start the motor; (allow some 20 seconds to accelerate to full speed, automatically apply the field at the proper instant, and pull into synchronization). If starting is unsuccessful, the high voltage circuit breaker will trip out, and a waiting period is required before attempting to restart.

Stopping Windbox Fan -- Normal stopping begins with tripping the fan switch. Interlocks reset the Askania regulator timer, closing its contacts and thus driving the damper to its closed position. A.C. power for field excitation is then turned off, and the regulator pump unit is stopped.

b. Control by Baghouse -- If the control is a baghouse, make sure all chamber doors are closed and latched, and that no more than the prescribed number of chambers are on maintenance settings, which isolate them. Close the inlet damper. When the gas temperature in the bypass duct before the baghouse reaches the desired set

point value (70°C or whatever is needed to exceed the dew point) start the motor, turn on the fan load control, and close the bypass duct. Turn on the clean cycles and the dust screw conveyors.

Baghouse Shutdown -- To shutdown the baghouse, open the bypass duct, trip the motor switch, stop the reverse air fan and the conveyors.

c. Control by Scrubber -- If the control is a Venturi scrubber, and is to be started cold, all system equipment should be inspected with particular attention to where maintenance has taken place. Verify that no foreign objects have been left in the equipment or ductwork, and that all access hatches are closed and secured. Thereupon, startup may procede generally in the following sequence:

1) Start cooling water flow to the gas cooling tower and periodically monitor gas cooling water level alarms.

2) Most scrubber units have a classifier of some type to remove larger particles of the highly abrasive solid material that may be carried in the exhaust gases. If not removed, this material can be carried into pumps where the resulting abrasion can reduce the impeller life to a few weeks. The classifier (e.g., rake, screw conveyor, or hydroclone) should be started up at this time.

3) Start the water filter system. Generally the following sequence can apply: sludge hopper vibrator, drum filter agitator, thickener drive motor, thickener rake positioner, thickener underflow pump, drum filter drive, vacuum pump motor, filter air blower motor, and filter filtrate pump.

4) Start venturi pumps, and the attendant water flow flow recorders. Pump discharge valves may require manual adjustment to achieve the desired flow rate.

5) Start fan motor bearing lube pump (and fluid drive oil pumping if the system uses fluid drive) and system temperature recorders.

6) Start fan motor. Typically this is a constant speed motor, with the load controlled by adjustment of the venturi throat to allow for variations in gas flow while maintaining the cleaning efficiency necessary. When the sinter machine is started cold, the strand is covered with paper to partially limit the flow of air until burden is supplied. Scrubbers with a variable venturi throat sometimes are set to close the throat before

starting the fan. Others close a fan inlet damper to protect the fan motor during startup. At this time, such pre-start controls are set and the fan is started. (Note: automatic fan shutdown may occur due to high fan vibration, or motor overload). Adjust differential pressure controller and the motor power controller.

Scrubber shutdown -- Shutdown is essentially the reverse of the system startup procedure, depending somewhat on the anticipated duration of the shutdown. Under a short duration shutdown, the main fan is stopped, while lubricant recirculation systems, etc. continue to function. All water clarification equipment must continue to operate. Under a long duration shutdown, all scrubber equipment is stopped. Water clarification equipment is operated, however, long enough to purge the system of settled solids. In sub-freezing temperatures, water collection areas are drained or run at minimum water flow to prevent ice formation.

6. Start sinter machine.

   a. Permissive interlocks of equipment activated in previous steps will be closed so that the sintering machine may be started. Start the ignition furnace blower (the burners should not be lighted until the burden line is running).

   b. Start the sinter cooler drive, which actuates the breaker, vibrating conveyors and feeders to the sinter screens.

   c. Start sinter machine drive. (All safety rails and entry guides should be closed.) Set machine speed. When the drive is started, interlocks permissive to the roll feeder will close. If limits on the maximum torque during start are exceeded, the machine and all equipment permissive from it will stop.

7. Start the burden system. The roll feeder is permissive from the sinter machine, and will be started at this point if all emergency stop switches and the feed hopper overfill probe relay are closed. Startup includes the interlocked units from the roll feeder through the feed proportioning system.

8. Start vibrating feeder serving the dust collection system, which returns fines to the feed lines.

9. Light and adjust ignition furnaces.

10. Turn on and adjust water supply to balling drum (or alternative device).

11. Startup of product handling emission control.

a. Control by Baghouse

The startup procedure is essentially the same as the procedure for the windbox control, except that the by-pass of raw exhaust gases may not always be required. If required, it will generally be shorter of duration. There are two situations in which the by-pass may have to be opened:

1) there is a source of moisture within the emission control system and the gases are being fed below the dew point. Such a source may be the vapors which evolve when water is sprayed on hot return fines.

2) There has been a substantial change in atmospheric conditions in the time period immediately preceding the startup. Such a condition would be the sharp rise in atmospheric temperature and humidity which can result in condensation unless the colder steel of the baghouse is brought up to temperature by the heated gases from the sintering process.

b. Control by Scrubber

The procedure is the same as the windbox control except that the classifier will usually not be required or provided in the water circuit.

Shutdown

Shutdown of part or all of the process can occur when ever probes sense an abnormal condition, e.g., accumulation of material, parameter changes beyond limits, or equipment failure. Interlocks tend to actuate shutdown of equipment ahead of or directly related to the equipment the operation of which has suffered an upset. Five systems can be thus interlocked. Each is discussed in turn.

1. Materials receipt (recycled material, limestone, and fuel), screening, grinding, and transport to feed bins. This system shuts down independently if:

the rod mill (for fuel sizing) blower fails,
the rod mill lube pump fails,
the conveyors fail.

2. Hearth layer conveyors are shutdown when a high level of material is sensed in the hearth layer bin.

3. Raw ore processing, from receiving hoppers to feed bins shut-down when a high level of material is sensed in the screen feeder chutes. The feed circuit or parts thereof may be stopped if:

   someone opens any emergency switch,
   a thermal overload is sensed,
   the material level in the roll feeder bin gets too high,
   a backup of material of the feeder is sensed,
   the table feeder lube pumps fail,
   the sinter machine stops, or
   the conveyors fail.

4. The sinter machine may be stopped if:

   a part of the product handling system breaks down,
   a drive motor develops excessive full load torque,
   there is a lack of burden or hearth layer material,
   there is a jamb in the machine drive,
   the ignition furnace shuts down, or
   there is loss of suction in the windbox.

5. The windbox fan may be stopped if:

   bearings become too hot, or
   vibration becomes excessive.

3.0 CONTROL TECHNIQUES AND EQUIPMENT

3.1 WASTEWATER POLLUTANTS

Sintering is essentially a dry process. Water added to the burden to assist in its agglomeration is evaporated and passes out the stack as vapor. Water is sometimes used to control fugitive dusts, to facilitate the conveying of collected dusts, to cool the sinter product, or to minimize the possibility of spontaneous combustion in the windbox dusts if collected by baghouses. This water is unlikely to cause water pollution problems if it is returned to the sintering plant along with the collected dust. When a scrubber or a wet ESP is used as a control technique, the attendant wastewater must be treated and controlled. The wet scrubber could be a major source of water pollution if the effluent were not controlled. A venturi scrubber or a wet ESP will require a liquid to gas ratio (L/G) of approximately 1240 ℓ/scm. Typically, the recirculating effluent may contain up to 1600 ppm chloride, up to 520 ppm sulfur, a high amount of suspended and dissolved solids,[10] and have a pH of 2.1 to 3.1.[2,7]

Effluent New Source Performance Standards for the sintering industry have been promulgated in 40 CFR 420.25 and are shown in Table 3-1 together with characteristics of raw scrubber waters. The standards are based on the use of a tight water recycled system with only 0.2 liters of discharge per kg of sinter produced. The best available treatment methods for suspended solids are reported to be chemical polymer flocculation and settling in a clarifier, the overflow of which is recycled through the control device. The sludge drained from the bottom of the clarifier (underflow) is dried with a vacuum filter and the filter cake is landfilled. Oil and grease adhere to the suspended solids and are settled out with them or are skimmed off at the clarifier overflow. Aeration is required for sulfide treatment and lime is added for fluoride treatment and pH adjustment.

TABLE 3-1. UNCONTROLLED SCRUBBER WATER POLLUTANTS FROM A SINTER PLANT AND ESTIMATED CONTROL REQUIRED[a]

Facility Pollutant	Estimated Pollutant Loading, mg/ℓ Unless otherwise stated: Raw waters	Federal Stds. max, 1 day	mg/kg Sinter 30 day avg.	Water Discharge Limits L/kg Sinter	Control Efficiency Required[a] 1 day
Scrubber				0.2	
Total suspended solids					
(a) Using Blast Furnace Scrubber Water	341	15.6	5.2		99.9+[b]
(b) Using River Water	223				
Oil and grease		6.3	2.1		99.9+
Sulfide		0.18	0.06		
Fluoride					
(a) Using Blast Furnace Scrubber Water	24.3	12.6	4.2		99.9+
(b) Using river water	9.8				
pH					
(a) Using Blast Furnace Scrubber Water	3.07	Allowable Range 6 - 9			
(b) Using river water	2.95				

[a]Based on tests at one sinter plant. The scrubber pressure drop was 112 cm w.g. when using scrubber water and 130 cm when using river water. The increase was effected by adjustment of the scrubber throat.

[b]Based on L/G rate of 1240 liters/SCM of gas treated.

3.2 EMISSIONS AND SOURCES

Emissions from ten sources, are shown in Table 3-2. Of these, the windbox exhaust system is the most important because of the number of pollutants to be controlled and the high volume flow rate of exhaust air to be handled. The process equipment exhaust system is second in importance for the same reasons; this system (estimated at about 2400 scm per Mg of sinter poduct) may control the discharge hood, sinter breaker, and hot screens. The sinter cooler usually has no control of emissions except for those at the material tranfer points. Cold screens, conveyor transfer points, and conveyors may or may not be (but should be) controlled.

At this time, there are no National Performance Standards for Sinter plants. Standards of Performance for New Stationary Sources (40 CFR, Part 60, FR 38, 84, Wed. May 2, 1973) impose no standards for abnormal operating conditions, but require reports from plants when controls exceed mass emissions levels for compliance tests. State regulations do, however, impose limitations. Some representative state regulations are shown in Table 3-2.

3.3 TYPES OF CONTROLS USED

3.3.1 Windboxes

Electrostatic precipitators (ESP's), scrubbers, and cyclones are the principal current means for controlling emissions from the windboxes of sinter machines, while fabric filters are the preferred method for control at other points: sinter discharge, crushing, screening, material transfer. The distribution of air pollution control equipment used on windboxes of 45 sinter plants follows:[11]

Type of Control	Number of Plants
ESP	22
Cyclones	11
Scrubbers	9
Baghouse	1
Steam ejector	1
Mechanical	1
TOTAL	45

TABLE 3-2. UNCONTROLLED POLLUTANT EMISSIONS FROM SINTER PLANTS AND ESTIMATED CONTROL REQUIRED.

Facility, Pollutant	Production Rate Mg/day	Estimated Emissions, Kg/hr, Unless Otherwise Stated: From Primary Collectors	State Regs.	Reg.	Control Efficiencies Required	Possible Standard[a]	Opacity Standard	Monitoring Requirements
(1) Windbox Exhaust System								
Particulates, filterable	900	82	8-16-23	2,6-3-5,6	90-80-72	Particulate: 65 mg/kg strand feed	---	Operating Parameters[c]
	5400	572	33-37-38	5,6-2,6-3	93-93-94			
	13600	1224	37-43-61	5,6-3-2,6	97-96-95			
Particulates, condensible	All rates	0.2 gm/kg sinter	None Applicable	---	---	120 mg/kg strand feed	---	
SO_2	All rates	112 ppm[7] 0.9 gm/kg sinter	500 ppm	1, 2, 3	None	---	---	
CO	All rates	7000 ppm[8] 19 gm/kg sinter	None Best Avail.	--- 4	--- ---	--- ---	--- ---	
HC	All rates	2.4 gm/kg sinter[8]	None	---	---	---	1 %	Opacity[b,c]
NO_x	All rates	130 ppm[9] 0.7 gm/kg sinter	None	---	---	---	1 %	Opacity
Fluorides	All rates	0.05 gm/kg sinter	None	---	---	---	---	
(2) Product Handling Exhaust System		Uncontrolled						
Particulates	900	131[11]	7-13-23	2,7-3,12-5,13	98-97-94	---	---	
	6300	918	26-32-33	2,7-2-12,5,13	99-99-99	25 mg/std.m^3	1 %	Opacity
	13600	1983	36-37-56	3-5,12,13-2,14	99-99-99			
(3) Process Equipment								
(a) Raw Materials Handling							1 %	
(b) Discharge Hood							1 %	
(c) Sinter Breaker							1 %	
(d) Sinter Cooler							1 %	
(e) Hot Screens							1 %	
(f) Cold Screens							1 %	
(g) Conveyor Transfer Point							1 %	
(h) Conveyors							1 %	

[a] 1. Strand feed includes all materials fed to sinter machine except the hearth layer.
2. If windbox exhaust and process equipment exhaust emissions are combined prior to entering a common control device the combined discharge standards for particulate matter are prorated on the ventilation rate of process exhaust system.

[b] The opacity standard and opacity monitoring requirements do not apply if:
1. A scrubber or other control device is used which causes interference with opacity monitoring.
2. Windbox exhaust and process exhaust emissions are combined prior to entering a common control device.

[c] If one opacity standard does not apply, the operating parameters of the exhaust system control device are monitored (pressure drop and gas flow rate through control device and liquid flow rate to control device as applicable).

[1] Based on source test emissions after the mechanical collector. Windbox particulate emissions averaged 2.06 pounds per ton of strand burden. State regulations define particulate matter as any material that exists as a solid or liquid at 70°F and 14 lb/in^2 absolute pressure.

[2] Pennsylvania: Allowable = 0.76 (20 lb/ton feed x W tons feed/hr)$^{0.42}$ or 0.02 gr/dscf whichever is greater (for exhaust rates over 150,300 scfm, 0.02 gr/dscf is greater).

[3] Illinois Rule 203d (2): process weight for new sources x 1.2.

[4] Maryland

[5] Indiana

[6] Equivalent process weight regulation - based on total strand feed (excludes hearth layer). Test data indicates that production is approximately 43 percent of total strand feed.

[7] Based on source test data in Table 3-4.

[8] Based on source tests at Plants E and G.

[9] Based on source tests at Plants E and G.

[10] Based on source tests at Plants F and G.

[11] Based on 22 lb particulate per ton of product.

[12] Ohio

[13] Process weight regulation - Based on total strand feed (excludes hearth layer). Based on test data, production is judged to be 43 percent of total strand feed.

[14] Grain loading regulation - Based on test data; total air flow rate of processing operations is estimated to be 68,300 dscf/ton sinter product.

[15] Values set by EPA-AISI analysis.

The control of emissions from windboxes is made difficult by factors such as the high volume rate of gas, the sometimes high resistivity of the dust and the presence of hydrocarbon vapors and fluorides. Because of state opacity regulations, and the need to recycle oil-bearing wastes (see discussion under emissions from sintering), steel plants are being required to use high energy scrubbers and wet ESP's.[12,13,14] Generally, any final control unit will be preceded by a mechanical collector to remove the large, heavy, abrasive particles.

Electrostatic Precipitators (ESP's)

Sinter plant ESP's are typically single-stage, horizontal-flow units.[11] Figure 3 shows the gas flow plan. The power supply generally consists of a

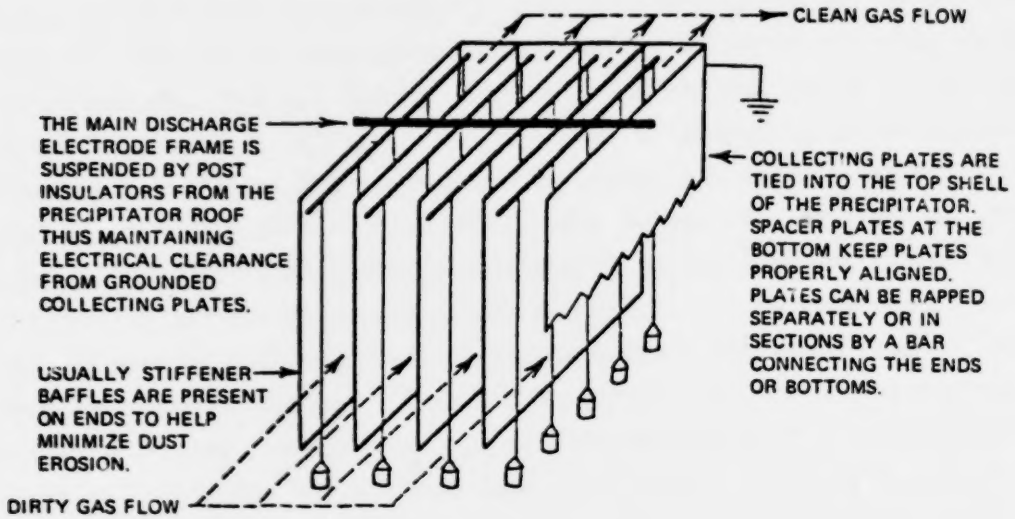

CLEAN GAS FLOW
THE MAIN DISCHARGE ELECTRODE FRAME IS SUSPENDED BY POST INSULATORS FROM THE PRECIPITATOR ROOF THUS MAINTAINING ELECTRICAL CLEARANCE FROM GROUNDED COLLECTING PLATES.
COLLECTING PLATES ARE TIED INTO THE TOP SHELL OF THE PRECIPITATOR. SPACER PLATES AT THE BOTTOM KEEP PLATES PROPERLY ALIGNED. PLATES CAN BE RAPPED SEPARATELY OR IN SECTIONS BY A BAR CONNECTING THE ENDS OR BOTTOMS.
USUALLY STIFFENER BAFFLES ARE PRESENT ON ENDS TO HELP MINIMIZE DUST EROSION.
DIRTY GAS FLOW

Figure 3. Typical duct electrostatic precipitator.

single phase, high voltage transformer, appropriate control equipment, and a bridge rectifier circuit, which may use a mechanical type of rectifier, or the newer Kenotron vacuum tubes, selenium, or silicon rectifiers. Normal transformer ratings are between 25 and 50-kva, 440 volt primary and 50 to 75 kv secondary. The collection area consists of duct collection electrodes with high voltage discharge electrodes uniformly spaced and of uniform length.

Collecting electrodes (metal surfaces that collect the particles) are at ground potential and are connected directly to the frame of the precipitator. Dust is removed by rapping or vibrating the plates. Material loosens and falls into collection hoppers for subsequent removal. Chambers and hoppers are usually fabricated of plain carbon steel, with or without thermal insulation. Plain-carbon steels have suffered from the corrosive action of acids formed in the gas by reaction of sulfur oxides with moisture. A high sulfur level in feed raises the acid dewpoint of the gases, leading to possible condensation. Air in-leakage will lower the temperature of the gases, thus favoring condensation. This corrosion increases maintenance costs, e.g., for replacement of electrodes, collector plates, and internal supporting members.

The collection process consists of charging dust particles with a corona discharge and then passing them through an electric field where they are attracted to the collecting surfaces. The collection efficiency of the ESP depends upon the effective collecting electrode area of the ESP, the particle migration velocity, and the gas flow rate through the ESP. The particle migration velocity depends in turn upon its size, the strengths of the electrical fields in which the particles are charged and collected, and the viscosity of the gas. The resistivity of the dust is a factor of major importance in the design and application of dry precipitators to sinter plants. Changes in the composition of the sinter can cause changes in the resistivity of the dust, the most significant sinter-relationship being that between the basicity of the sinter and the resistivity of the dust. Burdens suitable for production of low basicity sinter tend to yield a dust with proper resistivity for efficient precipitator operation (resistivity less than 2×10^{10} ohm-cm). In the steel industry, there has been a trend toward increasing the basicity of the sinter, often after installation of a precipitator. The reason for the trend is to improve the economics of production. Limestone is needed in the blast furnace to remove certain impurities such as sulfur from the iron. If this flux material is charged into the furnace as limestone, the heat to calcine the stone is supplied by lump coke, a high cost fuel. If the limestone is added, either wholly or in part, to the sintering process, calcining takes place there. Since the fuel for sintering is often relatively less expensive (e.g., Cuban coal, coke breeze), the cost of energy for calcining is lower in the sintering process than in the blast furnace.

High basicity sinter production yields a dust with a high resistivity (above 2 x 10^{10} ohm-cm). This is generally too high for good removal using a dry ESP, and the trend from low to high basicity sinter has thus caused an increase in emissions from the windbox stack. The high resistivity of the high basicity sinter dust can cause severe sparking between electrodes. When this occurs, the power input must be reduced to reach the desirable spark-over rate of 50-100 sparks per minute. As a result, efficiency can drop 5 to 20 percent below design values.[11]

Oglesby et al. have reported that ESP's for sinter plants are generally designed for a gas velocity of 1.3 m/sec; an inlet gas temperature of 118°C (although 150°C would be better for high basicity sinter); an electric field of 3.2 kV/cm; an inlet dust loading of 2.3 gms/actual m^3 (1 gr/ft^3); a precipitator power rating of 251 watts/100 m^3 gas per minute (251 watts/3500 cfm).[15] Depending on the characteristics of the particular operation, these parameters may be altered considerably. The resistivity of dust from a plant making sinter at a basicity of 4 was 1 x 10^{12} at 150°C.[11] Using power requirements for flyash of equivalent resistivity indicates that an ESP for this dust should have a corona power rating of 450 watts/100 m^3 gas per minute, instead of generally used 251. To meet a state regulation of 33 kg/hr (73 lb/hr) for a 5.400 Mg/day (6 tons/day) sinter plant (Table 3-2) with the design inlet gas loading of 2.3 gms/actual m^3, a collection efficiency of 98.5 percent would be required. (ESP efficiencies have been reported to exceed 99 percent[15].) The ESP would require an estimated 49000 m^2 (527000 ft^2) collecting plate area, and 73000 watts of power. In this case, the generally designed ESP would be considerably under designed.

If hydrocarbon vapors are present, opacity regulations are not usually met. One plant using an ESP showed a condensable hydrocarbon concentration in the outlet gas of 1.2 mg/scm (0.00051 g/dscf).[11]

Fabric Filters

A fabric filter has been installed on the windbox discharge of two US plants.[16,17,18] One plant (Kaiser) has operated the baghouse fairly successfully for several years. The plant is in a warm climate where the year-round high

temperatures help to avoid plugging the bags with condensation of hydrocarbon vapors. The plant has found it necessary to restrict oily feed materials to avoid problems with condensed hydrocarbons. A second plant, operating in a cold climate, has had difficulties with blinded bags, in consequence of which there has been increased emissions. A program there is underway to overcome this difficulty by changing to a slicker cloth bag material. At the same time, the construction of the bag is being altered to minimize its susceptibility to rupture. The value of these changes has not been yet determined.

Apparently collected dusts are pyrophoric. Heating takes place in the collection hoppers due to hydration of the alkali oxides which are present. Fire ensues when the temperature reaches the ignition point of the collected hydrocarbons. To avoid this damage with a baghouse, it has been necessary to rather severely restrict the use steel plant wastes such as mill scale, blast furnace sludge, and coke fines. These wastes must then be disposed of in an environmentally acceptable manner leading to increased costs and a loss of useful material.

The baghouse at Kaiser's Fontana Mill is a bottom-entry, reverse-load-clean filter. It consists of 14 compartments (7 per sinter machine), each containing 184 bags, 30 feet in diameter by 9.6 meters long. The air-to-cloth ratio is 74 cm/sec (1.47 cfm/sq. ft.) at 10195 cmm (360,000 cfm/min). Actual inlet conditions were found to be very close to design conditions, and include: gas temperature, 121°C-150°C; moisture, 6%-10% by volume; particulate, 686-1144 mg/scm; gaseous sulfur, under 500 ppm. The design provided for two baghouses under a single roof (Figure 5). The gases from the two sinter machines have been kept separated until discharged into the base of the stack. There were three reasons for choosing the 2-baghouse design. If one sinter strand were started cold while the other was running hot, a considerable amount of cold air would be introduced into this system, producing a cooling effect that could cause condensation and its attendant problems within the baghouse; since each machine had an independent fan, and these fans were running at full load, it was necessary to install those two fans in series with them to supply the added energy requirements of the baghouse. By maintaining separate gas systems, all air flow balancing problems between the machines were avoided. Third, the

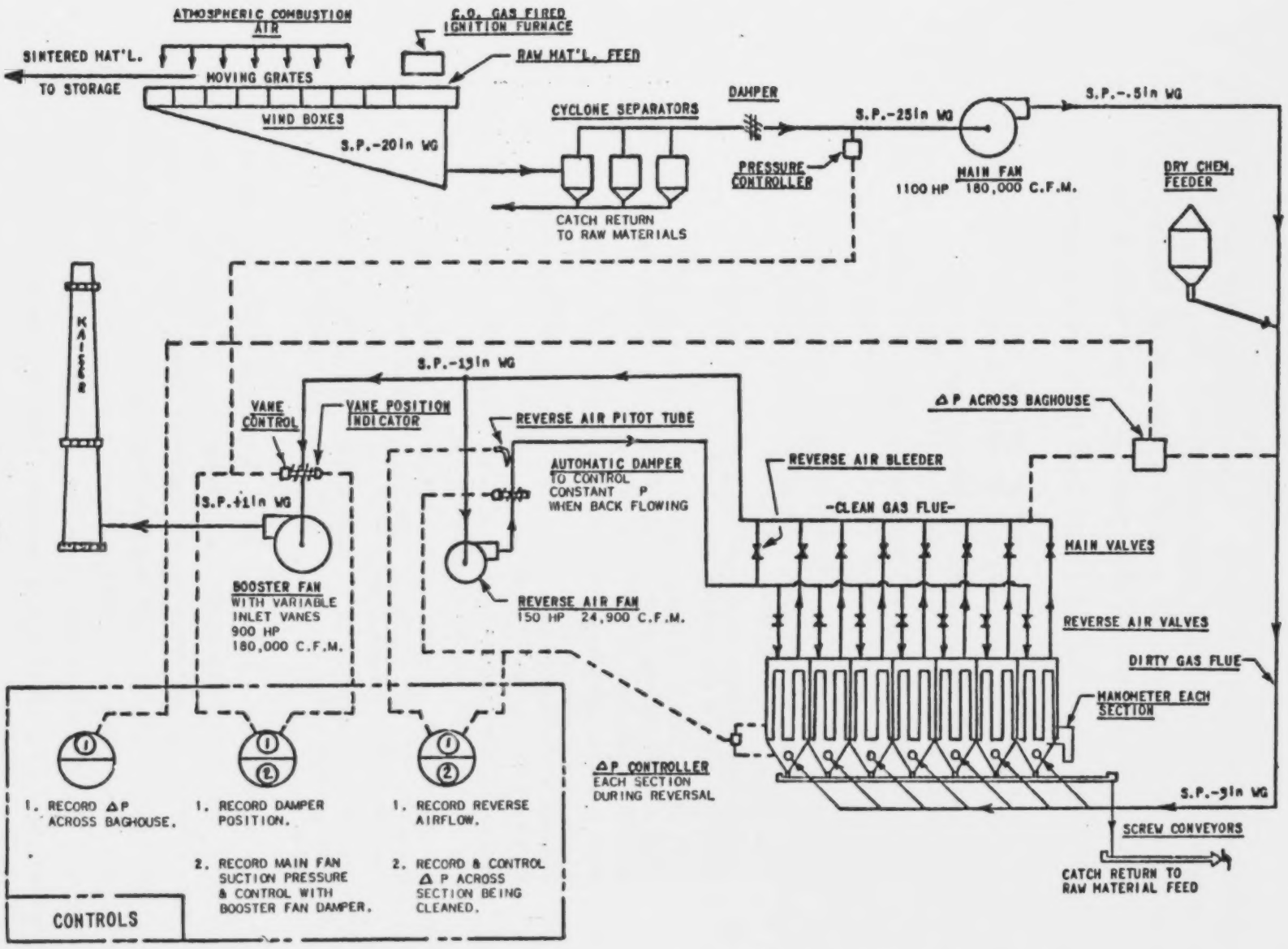


Figure 4. Schematic diagram showing flow and controls for a sinter plant baghouse.

baghouse is installed without a bypass. It was expected that most breakdowns could be handled on an individual compartment basis. However, with this separation a major bypassing could be avoided. The design features were selected based on experience with pilot models and include the following:

1. Valves were stem vertical, flat plate type, and positioned on the clean air side.
2. Air cylinder rods were kept out of the gas stream, thereby keeping them cool and clean and extending rod seal life.
3. All mechanical equipment was protected from the heat and located for easy servicing in relative comfort.
4. Clearance between bags was set at a minimum of 4 inches, to reduce the probability of the jet from a blown bag destroying an adjacent bag.
5. Elongated (45 to 61 cm) (18 to 24 inches) bag thimbles were provided to streamline the gas flow and minimize the possibility of wear at the bottom.
6. Trough-type hoppers were used for recycling the dust continuously to the sinter machine feed.
7. Side entry hopper screws, discharging through double flap tipping valves were installed to avoid maintenance problems connected with rotary valves.
8. Five sewn-in stainless steel, Heliarc-welded anti-collapse rings were used per bag. This controlled collapsing when reverse air cleaning was used, and prevented the bag from pinching off during reversal.
9. Provision was made to isolate a compartment for entry while the rest of the baghouse was operating.
10. An independent vacuum cleaning system was provided for cleaning the cell plates of dust that bleeds through the bags or comes through broken bags.
11. Completely flexible, easily monitored cleaning system controls were provided that could be readily varied to suit operating needs.

The bags selected were made of a 3X112, 8.9 ounce, silicone, graphite, teflon-coated, fiberglass fabric with a permeability of 17 cmm/m^2 (55 cfm/sq ft.). This material was selected for its superior temperature properties and chemical resistance. Only 12 bags had been replaced within a years operation. As aging continued, a bag-replacement rate of 12 per month has been experienced.

Isolated instances of visible plume from the plant stack have been observed under normal operation. Particulate removal efficiency has been measured at

better than 99 percent with a discharge dust load of the order of 4.6 to 9.2 mg/scm.

In operation, temperatures below 150°C are avoided if possible. The particular gases showed an SO_3 dewpoint in the neighborhood of 93-121°C. Condensation of SO_3 in the baghouse would be fatal to the bags in precipitation of gypsum in the filter fabric.

The fabric filter achieves only about 40 percent efficiency in removing oil charged to the strands. Because the light ends of the organic emissions are thus inefficiently collected, a significant stack emission will result if the oil to the sinter strand is excessive. A 40 percent opacity rating will be obtained if one or more of the following five conditions are met:

1. if the feed is greater than .01 percent oil,
2. if the coke breeze feed is greater than .1 percent oil,
3. if the baghouse dust contains more than 1.0 to 1.5 percent oil,
4. if the stack condensibles at 0°C equal or exceed 4.6 mg/scm,
5. if water fed to the pug mill contains greater than 0.01 percent oil (the feed is 10 percent water).

Scrubbers

High energy scrubbers offer better control of particulate condensible hydrocarbons, and, in addition, offer control of the fluorides and sulfur dioxide contained in sinter plant windbox gases. Both the venturi scrubber and the stream hydro scrubber have been tested in actual operation.

Armco's Middletown, Ohio sinter (recycle) plant, rated at 2395 Mg/day sinter product, uses a high energy, variable throat, orifice venturi scrubber with an adjustable plug.[12] The windbox gas cleaning system (Figure 5) consists of, in sequence, dry primary and secondary cyclones, two induced draft fans in series, the wet scrubber, and a cyclonic mist eliminator with a stub stack. The system is designed for 8630 acmm (304,500 acfm) at 150°C with a venturi pressure drop of 114 cm w.c. with an outlet loading of 46 mg/scm. Water is supplied to the scrubber throat and inlet at 6813 ppm recirculated from the mist eliminator tank. Makeup water to the mist eliminator is at 1514 ppm from other sinter plant noncontact cooling water sources. A blowdown of 1230 ppm from the bottom of the mist eliminator is pumped to the blast furnace sludge settling pond and becomes part of the blast furnace system blowdown. The pH of recirculated water is controlled using hydrated lime.

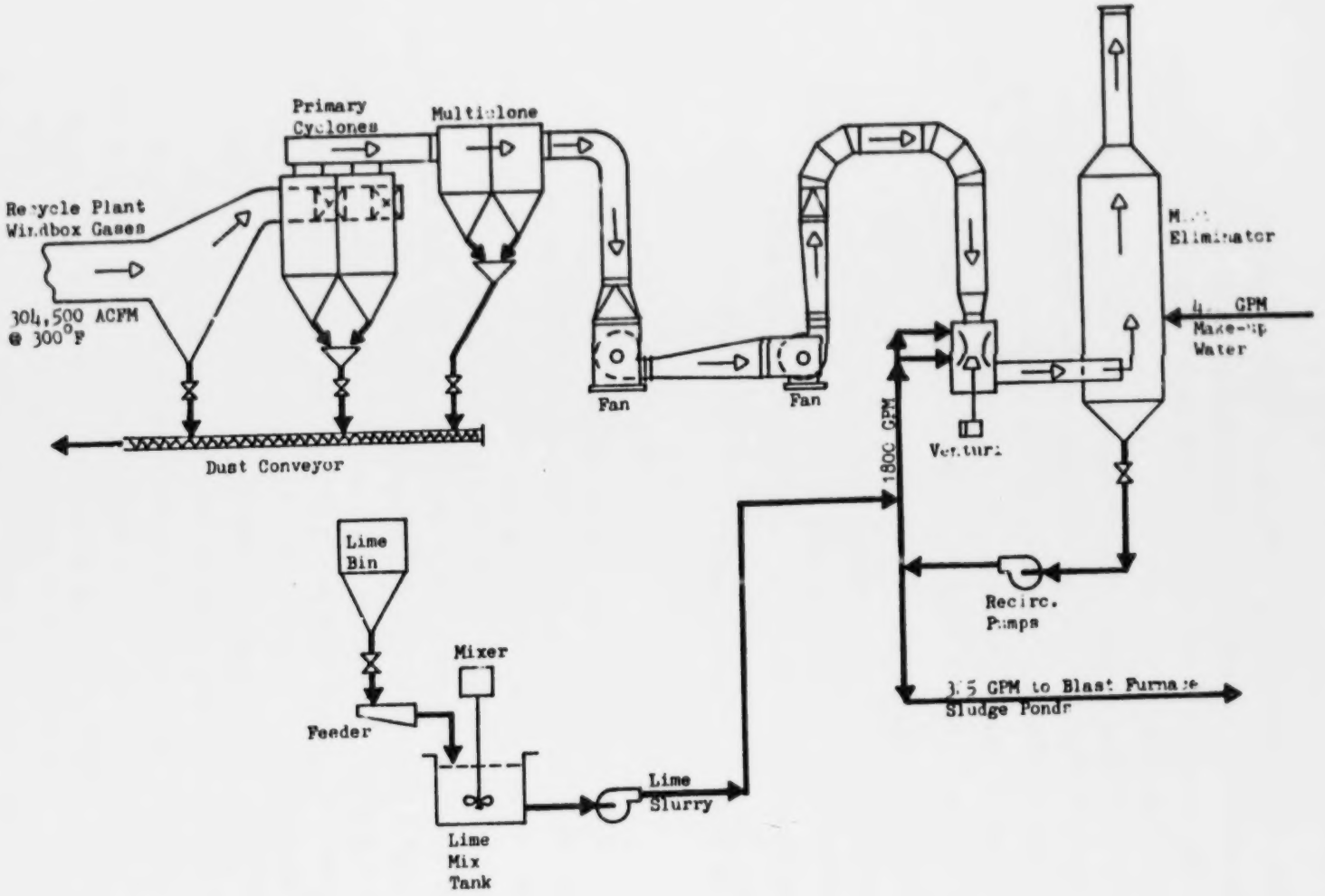


Figure 5. Recycle plant, Middletown Works scrubber system flow diagram.

Armco's Houston Works 1430 Mg (1360 kkg/day) sinter plant installed a Lone Star Steel Steam-Hydro scrubbing system in 1975, to control stack opacity.[12,19] This system was considered the best, economically, due to the availability of low cost steam generating capacity at the time of initial installation. This may no longer be the case due to sharp increases in the cost of natural gas. The system (Figure 6) consists of six parallel units, one serving as a spare. Each unit consists of (1) a combination steam-water nozzle where the steam atomizes the water droplets, (2) a mixing tube, where the particles and droplets contact, and (3) twin cyclone separators where the particle-laden droplets are removed and the clean gas is discharged through the stub stacks. An existing induced draft fan supplies dirty gas to the units, and the motive force of the steam forces the gas through the gas cleaning system. The system reduced an inlet gas particulate load of 1146 mg/m^3 to 68.9 mg/m^3. Actual emissions translate to 17.5 kg/hr versus a regulation allowable 41 kg/hr. Some periodic opacity problems exist.

Tests made on normally operating existing steam hydro units show an opacity rating of 7.4 percent (6 min average, EPA Method 9).[38] This opacity value would exceed limits under consideration for proposed New Source Performance Standards.

Data obtained using a pilot venturi scrubber (Kinpactor, adjustable throat) indicate that hydrocarbons (oil) are collected in the demister that follows the scrubber proper. The oil is collected either as droplets or adsorbed on solid particles.[31]

Control of hydrocarbon emissions by this venturi scrubber system was shown to depend upon three factors listed in decreasing order of importance: the concentration of hydrocarbons in the inlet gas; the particle size of the hydrocarbon mist; the pressure drop across the venturi throat. The relative importance of inlet oil levels in emission control was shown by regression analysis of the data: the correlation coefficient between the oil outlet concentration and oil inlet concentration was 0.49; that between oil outlet concentration and venturi pressure drop was 0.06. These data were taken over a pressure drop range for the venturi of up to 115 cm w.c. It is apparent from these correlations that the most critical factor in controlling oil emissions when using

such a scrubber is the control of oily emission from the sinter strand itself. To a lesser extent, the maintenance of adequate pressure differential is needed.

As a result of this inherent behavior of the system, the efficiency of oil removal seldom exceeded 80 percent. Hydrocarbon emissions limits set for the scrubber were not greater than 69 mg/scm. To meet this level, it would be necessary in this system to limit the hydrocarbons in the inlet gases to a value not exceeding 230 mg/scm.

Several methods of control could be used in conjunction with the scrubber to insure desired hydrocarbon emission abatement, when the quantities of hydrocarbons released from the sinter bed exceeded the capability of the venturi scrubber. These include: regulating the hydrocarbon content of the burden feed material; adjusting the ratio of ore feed to other materials in the sinter mix; recycling a portion of the oil laden windbox gases through the burning bed; incineration of the stack gas after wet scrubbing. However, incineration is not a viable approach from either an investment or fuel standpoint.

Scrubber water discharges are either "once through" or recycled through a thickener. The thickener underflow is decanted with centrifuges or vacuum filters. The filtrate is returned to the thickeners. The filter cake is returned to the sinter plant. When high energy scrubbers are used, magnetic or chemical flocculation may also be required.

Where scrubbers are used, a range of net plant raw waste loads in the untreated wastewaters are as follows:

	Raw Wastewater	Treated Effluent*
flow, ℓ/Mg of sinter	434 - 1420	
susp. solids, mg/ℓ	4340 - 19500	25
oil and grease, mg/ℓ	457 - 504	10
fluoride, mg/ℓ	0 - 0.644	20
sulfide, mg/ℓ	64 - 188	0.3
pH		0 - 9

*These are estimated results of the best available technology economically achievable for wastewater treatment: (1) classifier, (2) thickener with chemical flocculation, (3) thickener overflow recycled to scrubber with blowdown treated by settling, aeration, lime neutralization, and sedimentation. An oil skimmer is added to the thickener.

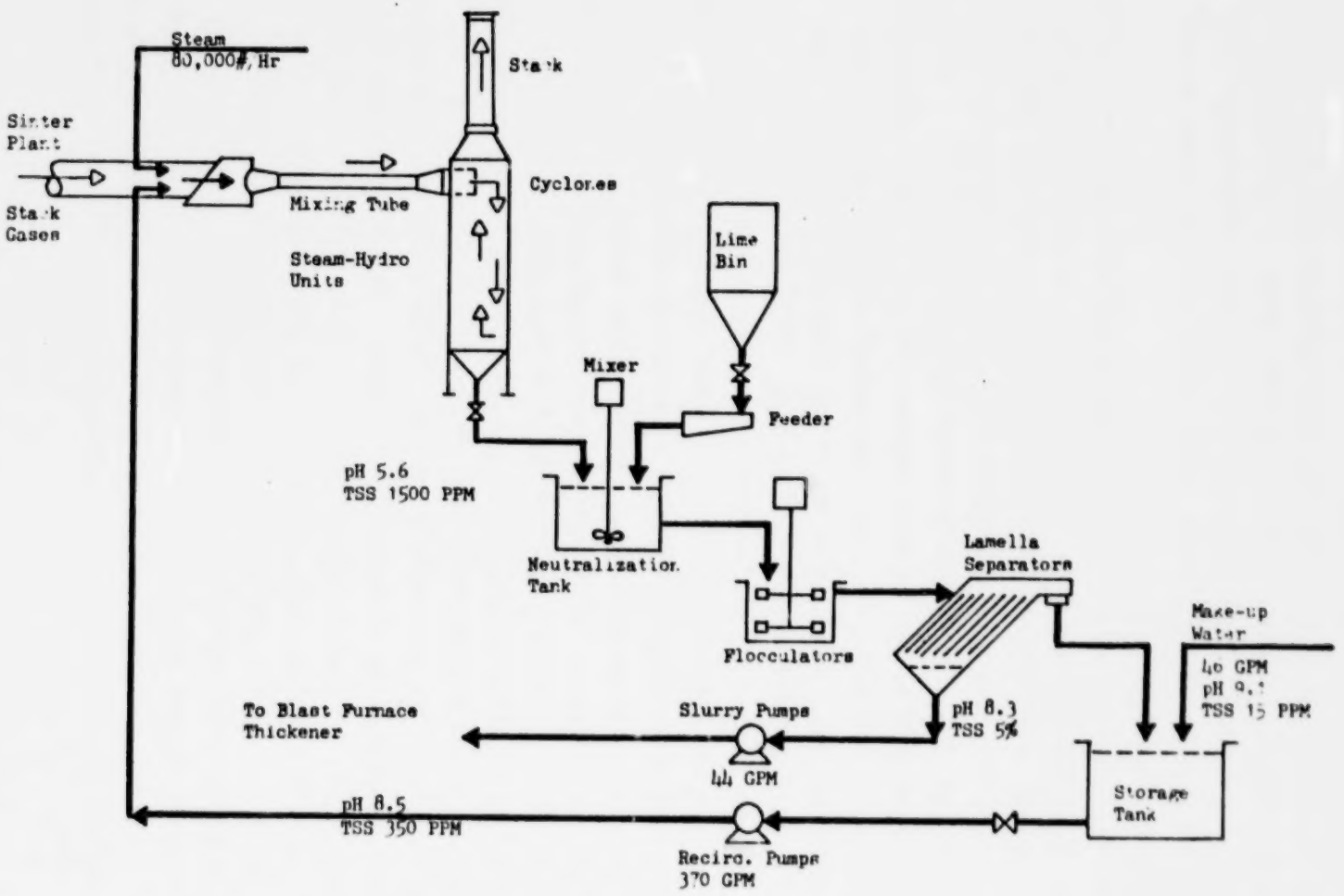


Figure 6. Scrubber plant, Houston Works, scrubber system flow diagram.

Wet Electrostatic Precipitators (WESP'S)

Wet ESP's appear to be a potential feasible alternative to wet scrubbers. The water wash provides a clean collecting surface, tends to prevent reentrainment of the particulates, and cools the gas with attendent condensation and collection of some of the hydrocarbons. Water may be injected ahead of the WESP to saturate the exhaust gas.

Most of the experience with WESP'S has been acquired while testing pilot plants. One full scale system is in operation and is not performing satisfactorily. However, a full-sized WESP module at another plant has operated since August 1976, together with associated liquor handling facilities for control of a windbox gas slip stream (of about 2000 acm/min).[14,20]

Two types have been tested in pilot plants. One, supplied by the MikroPul Division of the U. S. Filter Corp., was a horizontal flow precipitator continuously wetted by water sprays directed at the inlet baffles and internal components.[21] The equipment arrangement is shown in Figure 7. A slip stream of windbox gas was fed to this system from a sampling location downstream of large twin cyclones and upstream of a full-steel dry ESP. The pilot study ESP liquor-handling system was operated in once-through and recirculation modes, both with and without pH control for the recirculation mode.

The throughput rate was limited by the existing capabilities of the WESP pilot unit. When operated up to maximum gas flow rates thus limited, the outlet particulate loadings were consistently less than 69 mg/dscm, regardless of the gas flow rate or strand mix tested.

The main difficulties with this system were those associated with operation in a recirculating mode using minimum blowdown. The recirculating liquor tended to have a pH of 3 and to contain 500 ppm of fluoride ion. It was excessively corrosive for the design of facilities utilizing available "corrosion resistant" austenitic stainless steels, etc., Type 316L. When pH control was tested, it became necessary to provide a pH of 10 liquor to the sprays in order to control the WESP discharge water at a pH of 7. As a result, calcium and magnesium carbonate deposition occurred in all parts of the system including WESP spray nozzles. It was concluded that a satisfactory WESP system

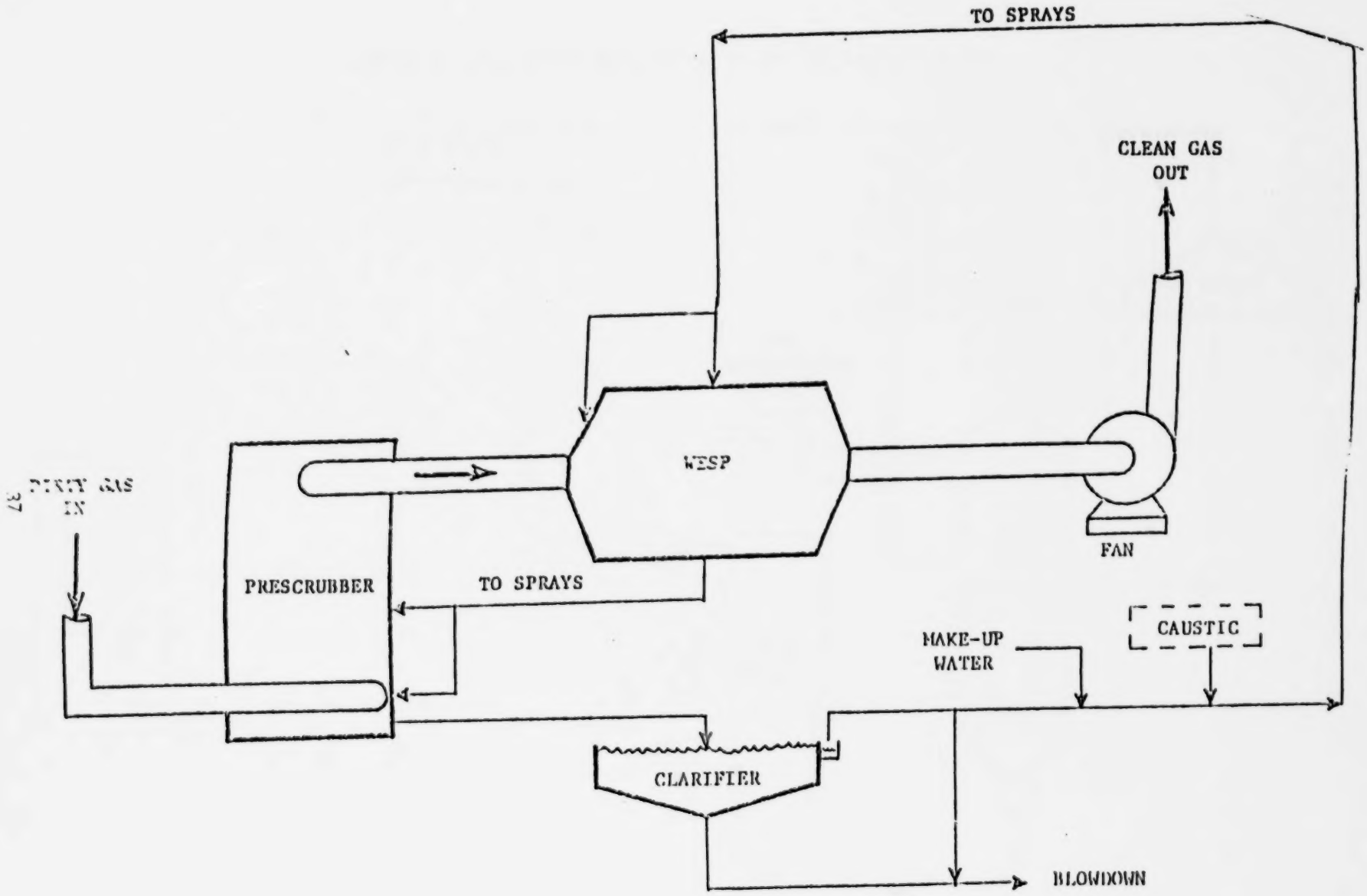


Figure 7. Mikropul pilot WESP test setup at a sinter plant.

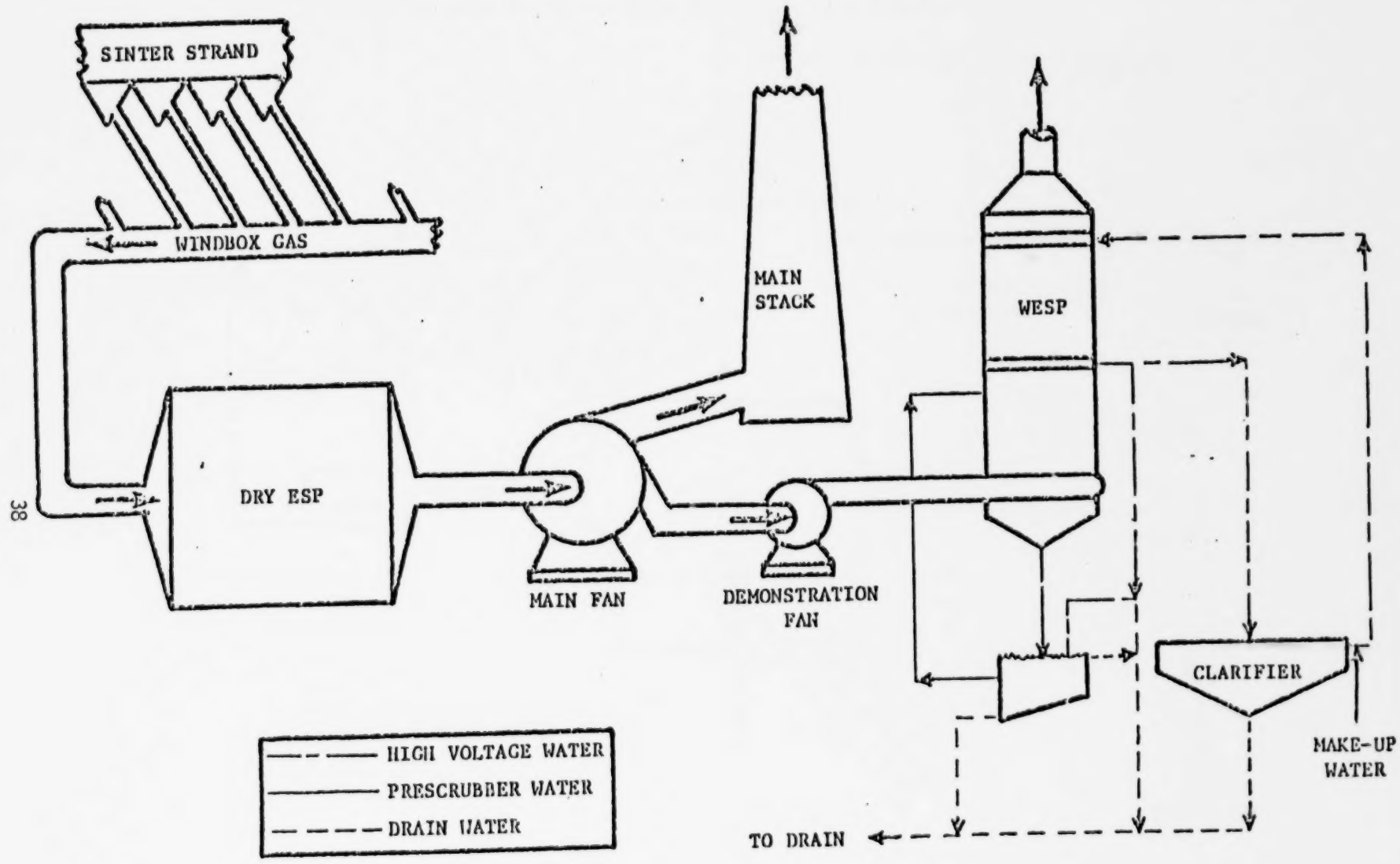


Figure 8. Full scale WESP demonstration at a sinter plant.

would have to be capable of being operated in the recirculating acidic liquor regime. The second WESP tested was a FluidIonic Systems Division of Dart Industries, Inc. model. This design (Figure 8) utilized a cyclonic-entry prescrubber spray system and straightening vanes, above which was located a precipitation section. The high voltage section consisted of a concentric array of a discharge electrode (an expanded metal cage) and fiberglass reinforced plastic collection cylinders. The cylinders were continuously flushed with a water film provided by water distributors mounted on the top of the cylinders. The system, including its water handling facilities, was modified based on early pilot tests, in a full-size single WESP module was installed to clean windbox gases. The unit was installed downstream from a full-scale dry electrostatic precipitator.

Baseline tests were made with a sinter plant base-to-acid ratio equal to 0.85. The system was operated at a maximum gas flow rate, typically 1925 acm/m at 120°C. This rate was slightly less than half the entire flow rate of windbox exit gases from the sinter strand. Power consumption at the primary side of WESP high voltage supply transformer was typically 20 amps and 210 volts, i.e., the WESP required about 1 percent of the power that would have been consumed by a high-energy scrubber for an equivalent outlet gas cleanliness. The tests conducted under baseline conditions showed outlet particulate loadings ranging from 7 to 50 mg/dscm. The average loading was 27 mg/dscm, including all the dry particulate matter and the organic-solvent extractable matter (hydrocarbons). The single test result which showed 50 mg/m^3 outlet loading corresponded to an abnormally high inlet loading of 1960 mg/m^3.

Outlets loadings were also affected by the basicity; when basicity was changed from 0.85 to 1.5, the particulate plus hydrocarbon loading increased in the outlet gas from 27 to 41 mg/dscm.

In assessing the performance of this WESP it is important to recognize that the system operated on a gas stream that had previously been treated with a dry electrostatic precipitator. With this precipitator turned off, dust concentrations at the inlet to the WESP were increased to values in excess of 4500 mg/dscm, and the emissions from the WESP increased to as much 103 mg/dscm. Despite the fact that the dry ESP was in operation, emissions through the WESP

during a cold start of the sinter strand exceeded those associated with steady state operations. (For an inlet loading of 2450 mg/dscm, the outlet loading was 210 mg/dscm of which 13 mg/dscm was hydrocarbons and the balance inorganic (nonextractable particulates). These abnormally high emissions were reported to prevail for only up to about one hour.

For every operating condition the opacity of the fumes from the demonstration stack was less than the main stack. However, at times plume opacities in excess of 20 percent can be expected from a full scale system, even at outlet loadings of 23 mg/dscm or less. It was observed that when gas flow rate through the WESP was reduced, the outlet particulate loadings were correspondingly reduced. It is anticipated that greater outlet loadings would be obtained at greater gas throughputs. Apparently the performance of this system is affected by the gas throughput rate.

Gravel Bed Filter

A 24 module gravel bed filter system is under evaluation by the Wierton Steel Division of the National Steel Corporation. The filter has been used in connection with windbox gas recirculation and in that mode, the outlet gases have been cleaned to 23-114 mg/dscm. At dust loadings below 46, the stack is clear. The filter requires a gas pressure booster fan and reverse flow cleaning fan. It is a totally dry system, however, with relatively low capital investment. At this time, with gas recirculation to reduce the hydrocarbon loading, the filter merits further study. It is of particular interest because the system is dry and avoids the problems of handling scrubber water. Initially operating problems occurred in the proper function of the gas valves which control switching from normal flow to reverse flow for the purpose of cleaning the bed. These problems have apparently been overcome.

3.3.2 Product Handling

Product handling control is primarily concerned with the sinter breaker, screens, coolers, and the associated conveyors. These points of emission can be hooded and the dust aspirated to one or more collectors. The sinter is generally cooled by air, although water sprays are sometimes used.

Mechanical collectors, followed by either fabric filters or low energy wet scrubbers have been used for dust control. Another technique used in various modifications is to direct the discharge exhaust to a hood located over the sinter strand to serve as a (preheated) portion of the process air. Dust so returned is filtered by the sinter or passed to the windbox waste gas system. One plant using this approach was unable to sufficiently to move all the processing exhausts through the strand.

The suppression of dusts by water sprayed onto the hot sinter is an inadequate emissions control technique. Even the careful addition of water treated with a surfactant will not eliminate emissions associated with mists or steam and the spray nozzles require regular and careful maintenance. The addition of water to the hot sinter causes fractures and spalling of the sinter and, in consequence, degrades the sinter product.

The fabric filter is the best demonstrated collecting device for product handling emissions control. In designing a suitable baghouse, the high abrasion characteristics and temperature of the dust require special consideration. A primary mechanical collector could be used prior to the filter to remove large particles and sparks. Bags made of silicon treated fiberglass, in use with reverse air cleaning, have lasted 18-24 months. Air to cloth ratios varied from 0.74 to 3.7 cm/sec. Most units consist of several compartments, with one serving as a spare.

The fabric filter can reduce inlet loadings to one hundredth their value over a reasonable range of gas flow. Better performing units are characterized by lower air to cloth ratios, wider bag spacing (e.g., 29 cm diameter bags on 35 cm centers), construction that facilitates inspection and maintenance, and outlet dust loadings of 10-12 mg/scm dry basis. Outlet dust loadings up to 23 mg/scm are within the range of presently operating scm baghouses.

The minimum quantity of ventilation air handled by the product handling exhaust equipment must be sufficient to assure that the fugitive emissions from the process are drawn into the collection hoods and enclosures. This amount is related to the process equipment configuration, hood and exhaust system design. Thus the necessary exhaust air volume is only nominally related to the sinter plant capacity.

Based upon available test data, a baghouse that controls particulates to less than 25 mg/scm should show an opacity (visible emission) level of less than one percent (6 minute averages, EPA Reference Method 9).

3.3.3 Materials Handling

Fugitive emissions escaping the raw material handling equipment are largely confined within the building in which they are usually carried out, and primarily affect the worker environment. The normal practice of handling materials that are moist alleviates the need for hoods and ventilation of conveyor transfer points. Water sprays can often be used to wet the material at transfer points.

Water sprays by themselves may be effective on such materials as dry ore. They are not effective in control of hot fines. Sprays cause steam clouds which entrain dust, also dust is hard to wet. If water sprays are used in evaporation with hooding, the moisture is carried to the baghouse where it may cause problems of bag plugging.

Where fine steelmaking dusts, dry ore fines, dry screened sinter fines, and similar materials are handled, separate fabric filters are the most common means of control.

There are numerous sinter cooler configurations, and many are forced-draft rotary coolers discharging through a stack. Cooler exhausts can contain entrained sinter dust. Most, however, show no visible emissions if the sinter is properly screened ahead of the cooler. A cooler emission of 1.7 kg/Mg of sinter has been measured, however, and at least one plant has installed a fabric filter on a cooler discharge.[23]

3.3.4 Process Modification

A recent variation in the design and operation of sinter plants is to recycle about 40 percent of the gases from the windboxes at the entry of the sinter machine to the top of the bed at the discharge end of the sinter machine. This has two advantages. One is that it reduces the quantity of gas passing through the final control device, thereby reducing the last emission rate at any given concentration of particulates. The other is that it provides control of emissions of hydrocarbons. That portion which is recycled is incinerated partially when it is passed through the glowing bed of sinter.

Windbox gas recirculation combined with a gravel bed filter may find a place for controlling particulates at future sinter plants. The energy requirements are estimated to be less than two percent of the amount required to produce sinter.[24] Preliminary test data indicate filterable particulates may be reduced to the same level achievable with a high energy wet scrubber.[25] Typical inlet gas loadings reported for the tests were: particulate matter 497 mg/scm; condensible hydrocarbons 160 mg/scm. The filter outlet particulates have ranged from 23 to 114 mg/scm; at loadings below 46, the stack shows no opacity. The effects of inlet dust concentration, gas flux rate (cm/sec), and particle size are under investigation.

One plant has gained better control of windbox emissions by adding the collected product handling emissions to the windbox gases as they are conveyed into the windbox baghouse. The addition of the hard abrasive particulate material from the product handling baghouse has been demonstrated to condition the windbox emissions for better collection at the windbox control baghouse.[25]

4.0 ABNORMAL OPERATING CONDITIONS

This section discusses abnormal operating conditions and techniques for eliminating or minimizing discharges thereunder. Abnormal operating conditions (AOC) can occur in the sintering process and in its control equipment. In addition, startup and shutdown difficulties are included. These are all addressed relative to resulting increases in pollution. From this perspective, their causes may be inherent difficiencies in the design of equipment relative to standards set for pollutant control, changes in operating practices and feed material, limitations in the applied technology, equipment or power failure. In assessing AOC's, therefore, attention is given to the role of and need for redesign of control equipment, preventive maintenance, redundant capacity, sensing impending upsets, and alternative strategies for response to AOC's at the plant. The application of various strategies in a given plant will depend on the availability of space and the characteristics of the particular system, and requires process engineering effort.

4.1 PROCESS RELATED AOC'S

4.1.1 Startup

When the sintering machine is started after a shutdown of one turn or more, it requires about an hour for the process to achieve full operating temperatures. During this period of time, condensation may take place in ductwork and in dust collection equipment. If the latter is a baghouse, the condensation may cause plugging of the bags and it may be necessary to bypass this type of pollution control during startup to prevent plugging. Precipitators are usually not powered fully until the gases have become warm enough to evaporate condensed moisture (Section 4.2). In both cases, a cold startup involves an hour or so of uncontrolled emissions, which can vary from 400 - 750 mg/scm.[26] Startups can occur once a week, due to normal downturns.

A cold startup can result in increased emissions (e.g., a cooler gas will tend to have higher hydrocarbon loadings). No data are available to show the

extent of additional emissions. Mazer, et. al. show an inlet loading increase (to a Wet ESP) from a baseline value of 900 mg/dscm to a cold start value of 2450 mg/dscm. Outlet emissions (for the Wet ESP) increased from 23 to 210 mg/dscm, with a threefold increase in outlet hydrocarbon loadings from 4.6 to 13 mg/dscm. One advantage of a high energy scrubber on the windbox gases is that this type of equipment shows substantially no decrease in performance under startup conditions.

4.1.2 Shut down

Stopping the sinter strand without stopping the fan(s) can result in burn through of the ignited burden while it remains stationary. This allows the temperature of the windbox gases and the characteristics of its pollutant load to change.

The frequency depends on how reliably the systems supporting the sinter strand perform without upset. The duration would be expected to be about 25 minutes, or the time required for burn through at normal strand speed. No data or estimates of the extent of additional emissions are available.

Normal shut down usually involves reversing the startup procedure, e.g., stopping the main fan and strand. No increase in emissions is anticipated from such a shut down. Some increase in fugitive dusts would be expected as the strand is cleared of burden, if this is done after the fan is stopped.

4.1.3 Abnormal Operating Conditions

The major AOC's of a sinter plant are mechanical and electrical. The major problem in operating the sinter plant is maintenance. The raw materials, and especially the sinter, are highly abrasive. Special materials of construction and continual attention to points of wear are mandatory. Distortion of the grate bars due to heat allows an excess of the sinter feed to pass into the windboxes. Special alloys for the grate bars and the use of a hearth layer can relieve this condition. Excessive leakage of air into the process overloads the suction fans and the dust collecting equipment. This can be avoided by maintaining machine seals, eliminating holes in the sinter bed, eliminating holes in the ductwork, and persistently maintaining the flapper valves which discharge dust from the windboxes and the suction mains.

Good maintenance, periodically scheduled during reasonably frequent planned down times, is the best way to alleviate the effects of malfunctions.

Plant shutdowns for one eight hour turn each week or two to do routine maintenance are common practice.[26,27] What is done will depend on the needs identified by daily inspection of the operating system, and is best illustrated by example. The following exerpt from one of the plants maintenance schedules shows thorough attention to 16 mechanical items, 4 electrical items, and 12 labor items considered necessary at the time.[28]

MECHANICAL

1. Changed 3 crusher teeth. Tightened loose bolts in teeth and hard surface welded door.
2. Changed discharge deck plate; tightened bolts in leaf springs.
3. Changed 6 bags and stripped #4 cross conveyor for cleaning, changed V-belts on same, Main Stack Baghouse. (4 men-32 hrs).
4. Changed both 24" x 38" bend pulleys for counterweight pulley.
5. Repaired and readjusted hearth layer gate - insulated new swivel hangers.
6. Changed pallets and replaced 3 axles and wheels.
7. Repaired scrapper (will change 1/7/77 with new assembly).
8. Repaired and replaced scrapers and clamps on seven conveyors.
9. Changed lo-speed drive reduction coupling.
10. Pulled pallets for furnace drilling. Blew out impulse lines for all furnaces.
11. Replaced 30' section of 4" diameter pipe for make-up strainer water.
12. Blew out spray headers and repaired water leak for dust suppression line.
13. Repaired doors on screening building.
14. Welded patches on windboxes as needed.
15. Welded fan blades and rebolted wear liners - rebalanced fan.
16. Checked and made repairs to drags.

ELECTRICAL

1. Cleaned and tested tilt switches.
2. Installed safety disconnect switch at machine.
3. Cleared ground terminal block at sinter cooler feeder.
4. Furnished temporary lighting and welding equipment.

LABOR

1. Cleaned sinter feeder decking and inclines.
2. Cleaned standard feeder decking, head to tail.
3. Cleaned sinter breaker.
4. Cleaned return fines conveyor.
5. Cleaned hot fines floor.
6. Cleaned operating area floors.
7. Cleaned top of store room.
8. Cleaned burden mix conveyors.
9. Cleaned screen decking.
10. Cleaned burden materials system.
11. Cleaned and emptied roll feed hopper.
12. One laborer worked in Main Stack Baghouse.

In response to increasingly stringent environmental control regulations which require reduction in the discharge of steel plant waste products to the atmosphere, receiving streams, and solid waste disposal sites, sintering plants have been and probably will continue to be recipients of increasing quantities of materials previously disposed of to the environment.[13] This can result in alteration of the operation in terms of departure from conditions for which the control system was designed. The base to acid ratio (B/A) and the concentration and characteristics of reverts both have significant effects on windbox aerosols. While the mechanics by which these factors exert their effects are not completely established, the effects have been repeatedly observed. An increase in the B/A ratio usually is accompanied by an increase in the concentration of KCl and NaCl fume generated upon sintering.[13] Blast furnace flue dust can contain K_2O and Na_2O distilled from the blast furnace burden. Thus, flue dust contributes to the generation of hard to

remove KCl and NaCl fume in the sinter plant windbox aerosol. Mill scales charged to the sinter mix may contain oils from the rolling operation. These would enhance the hydrocarbon concentration of the sinter plant aerosol. Other reverts that may contribute adversely to the sinter strand aerosol include, e.g., filter cakes from water treatment facilities which provides increased amounts of hydrocarbon and chloride, and coke breeze which also contains hydrocarbons.

Transient departures of any of these factors from their design levels can alter the pollutant load in the gases fed to control systems; if the departures are sufficiently great, they can alter the emissions from the controls. Persistent departures from normal operation (e.g., making a sinter of higher basicity than that for which the system's controls were designed, Section 3.3.1) can result in continuous excess emissions.

The production of sinter of higher basicity can alter the resistivity of particulate emissions and lead to lower ESP efficiency, with a corresponding increase in emissions.[11] The effect is intermittant if due to malfunction in feed bins such that excessive fluxes are added to the strand feed mix. It is persistent if increased basicity is maintained.

Increased strand loading with oil-bearing materials can raise the inlet HC load to the ESP and lead to increased emissions. No data or estimate of the extent of additional emissions are available.

Excessively oily or greasy mill scale in the burden mix can produce a blue hydrocarbon plume, the intensity of which, in the case of control with scrubbers, tends to be inversely proportional to the pressure drop.

Lack of control of burden moisture, or fuel, or ignition can lead to poor quality sinter with increased dust loading to the gas cleaning device. Good control of these factors will alleviate the problem. No data are available concerning the increased emissions; loadings of 2.5 to 10 g/kg of product would be expected.

Improper ignition yields either poor, spotty burning leaving unsintered material over the sinter bed surface, or if too intense, produces slagging over the bed surface leading to reduced sintering rates. Both are related to the proper distribution of coke in the burden. Unsintered material can cause increased emissions at the discharge end of the strand.

During burden preparation whenever fuel is not properly mixed throughout the bed some of the feed will not be properly sintered because there is no fuel available in the immediate vicinity. Where fine BOP dust is added to the burden, any lack of thorough mixing can lead to high dust concentration spots on the strand, and this leads to higher emissions. Where excessive oil occurs in spots resulting from lack of mixing, intermittant high stack opacities can occur. This would lead to increased emissions into the windbox and at the discharge and product handling stages of the process.

The key to minimizing abnormal emissions in the sinter plant is to take advantage of the continuous nature of the process and to pay careful attention to accurate proportioning of the feed material and adequate mixing to produce a uniform feed.

Use of excessive oil-bearing materials. There is some evidence that a given high energy venturi scrubber system may effectively reduce windbox gas hydrocarbon loadings only if the inlet loading is kept below a level set by the characteristics of the particular device. Coke, mill scale, and sludge all contain hydrocarbons. The feed composition must, therefore, be regulated by limiting the proportions of these (and any other) oily materials. These limits will depend on the oil content of the materials. One plant recommended that bedding be regulated so that mill scale and filter cake would not exceed 20 percent and 5 percent respectively of the feed going to the sinter plant.[8] When an acceptable ratio of hydrocarbon containing feed material to ore is exceeded, melt shop slag, pellet screening fines, and additional limestone slag could be substituted to improve the ratio.

Steam failure to steam hydro-scrubbers in series with a fan can result in increased emissions up to levels contained in gases fed to the steam hydro unit.

Product Handling

Screening station failure can lead to accumulation of unscreened sinter. If this is handled with front-end loaders and screened using unhooded screens, substantial quantities of fugitive emissions result.

When a baghouse is used, a bypass stack is usually installed upstream. This is opened to deliver gas directly to the atmosphere when its temperature is below a set value (about 65°C), to avoid condensation in the bags and plugging.

4.2 CONTROL EQUIPMENT RELATED AOC'S

There are ususally several pollution control systems operating in a sinter plant, as discussed in Section 3.0. Most of the systems have common features, i.e., ducting, fans, monitoring devices, and one of the three generic types of control devices. Therefore, many of the AOC's are common to more than one of the systems. Where a listed AOC occurs in only one of the systems or is more prevalent in one of the systems the narrative will provide this information.

4.2.1 Startup

Startup includes bringing the system on-line after a shut down for maintenance, rebuild, or strike, and bringing a new system into service.

Precipitators

Warmup

Most precipitator manufacturers recommend not energizing the precipitator until the gas temperature entering the precipitator has reached 66 to 93°C. Some prefer to have the unenergized condition remain for some time after this point to allow the collecting plates and wires to reach these temperatures. The intent is to drive off moisture which tends to condense on the internal surfaces. Condensed moisture is a problem for two reasons. On the collecting plates and wires it may cause collected dust to cake, leaving a layer not removable by normal rapping. Secondly, the frames that support the discharge electrodes (wires) are stabilized by insulators that attach to the grounded walls of the structure. Moisture on these insulators will cause dust to stick providing a conductive path across the insulator. This "tracking" can burn out the insulator, thus grounding a section of the precipitator until it can be replaced. Startup of an entire precipitator installation occurs frequently (at least once a week in a sinter plant).

The warmup period is about an hour for the windbox gases. The impact of the warmup period is varied depending on whether a full or partial precipitator is involved. Obviously, if a whole installation is involved all the particulate matter discharged from the process will be emitted during this period. If only one chamber out of a n-chambered precipitator is involved, about one nth of the total process particulate will be discharged in addition to the emissions that normally escape the operating chambers. The uncontrolled windbox particulate concentration is in the range of 450 - 700 mg/scm depending on the efficiency of the multiclone or other primary cleaning device upstream.[26]

If an unenergized warmup practice is followed, emissions may be reduced by energizing immediately upon startup at a reduced secondary voltage level. Operation at reduced voltage (change from automatic to manual operation, then adjust voltage manually) means that collection efficiency will also be reduced; however, reduced efficiency is better than no collection. Reduced voltage, however, reduces the potential for burning out insulators. The operator might find it necessary to increase plate and wire rapping (or vibrator) frequency intensities during this warmup period to reduce plate and wire buildups.

One plant following this practice of reduced voltage energizing has found that 60 percent of the normal operating voltage gives them good results, i.e., no insulator damage and partial collection. Certain types of electrical control sets make operation at these reduced voltage levels on a temporary basis more difficult. Most new sets are solid state static switch gear that can accomodate reduced voltage operation. Older electrical sets, particularly those with saturable reactors, do not work well under these temporary conditions.

Some plants may find they can operate during startup (without warmup) with no serious consequences. Experimenting on one chamber reduces the risk involved.

Preheating the precipitator is another means of minimizing warmup emissions. Use of natural gas just to preheat the precipitator is wasteful from a fuel economy standpoint, however.

Design of precipitators with individually isolatable chambers permits on-line maintenance of these chambers and would avoid the need to shut down the whole precipitator for maintenance. As a result the need to put a whole precipitator through the warmup period would be reduced in frequency.

Stack Puff

Stack puff refers to a momentary increase in particulate emissions, visually recognizable, leaving the process stack. There are stack puffs resulting from continuous operating problems, but stack puffs during startup are caused by particulate lying on the dust floor or attached to flow control louvers in the system reentraining into the gas stream. During a fan or system shutdown dust being conveyed by the gas stream settles onto the duct floors, and in the breeching between precipitator and fan. Also, where a single fan in a multiple fan system is shutdown, dead or low flow areas may develop in some duct runs leaving dust on the duct floors and flow control surfaces. Upon startup and shutdown as the fan damper position is being changed, the settled dust sometimes is picked up by the redirected air flow and carried out the stack.

The effect of this action is the greatest when the deposits are downstream of the collecting device where no chance to collect the dust exists. It also occurs upstream of the collector in which case the net effect is minimized by the collector.

The frequency in a multiple fan system can be as often as once per week, to as little as once per year in a single fan system. The duration of the puffs is widely variable. An estimate is one to five minutes, supported by observation of these and many other sources. No data or estimates of the extent of additional emissions are available.

No good corrective action for this AOC can be recommended. If dust dropout in the flues is an extensive problem during normal operation, it is periodically (perhaps once per year) necessary to remove the dust to prevent overloading of the duct structures. Since the dust deposits under normal operating circumstances, it is unlikely that dust puffs upon startup would be any less had the flue not been cleaned.

Unbalanced Flow Among Manifolded Fans

This is a startup problem peculiar to systems with multiple fans in a parallel flow arrangement inducing draft through a common precipitator. The

startup referred to is that of a single fan when the other system fans have been in operation. This would occur when one of the other fans is shutdown as a result of a failure or for scheduled or unscheduled maintenance.

Maintaining an even flow distribution among chambers of a precipitator is essential to maximizing particulate removal efficiency. In a manifolded fan system fans tend to draw more gas from the chanbers closest to them (path of least resistance) than those farther away (in a well designed flow system this tendency can be minimized by proper plenum sizing and the use of gas distribution devices). Flow control dampers may be located at the outlet of each precipitator chamber and balance restored manually, but the process is time consuming. After some experience it may be possible to reduce this time by having set points marked for the various possible fan combinations.

The consequences of unbalanced flow is reduced total collection efficiency for a number of reasons. Though a volume increase in one chamber is offset by a volume decrease in another chamber, the efficiency changes do not average out because gas flow rate is exponentially related to efficiency. The overall effect is reduced efficiency. Higher gas flow in one chamber may induce reentrainment of dust from the collecting plates.

Insufficient Draft, Fan Malfunction

Fan malfunction, either overheated bearings or motor bearings, motor overload, or vibration can be sensed by sensor controllers which feed back to shut down the fan. If so, the altered power to the precipitator can lead to lower particulate removal efficiency and increased emissions. Such fan abnormal operation can activate process shutdown if necessary to protect the motor. Most often, this is an upset that occurs in a control system with common multiple (manifolded) fans. Insufficient draft results from one fan being shutdown with a simultaneous failure of a spare fan to start. This upset potential exists wherever below-freezing temperatures occur. The upset was reported to have been due to ice in the fan housing. Condensed moisture accumulated and froze in the housing to a point where movement of the fan wheel was prevented.

The fan design, its inlet dust loading, its age, and the frequency of its regular maintenance all affect the frequency and duration of less efficient precipitator operation. One plant showed five mechanical fan rapairs in a four month period, during which nine regular shutdowns followed by maintenance were scheduled. Presumably, precipitator power adjustment occurred prior to each of these shutdowns. No data or estimates of the additional emissions are available.

Fabric Filters

Baghouses are generally protected from "cold" inlet gases during startup. Gases at temperatures below their dewpoint carry condensed moisture that will promote clogging of the bags when mixed with the solid particulate material. Moisture can also inhibit bag cleaning by causing the collected material to cling to the bags. Because of the total interaction between moisture and the collected particulates, the clogging is not overcome by simply drying the system with warm gases. The effect of condensed moisture is to increase pressure drop across the bags beyond the normal 10 - 15 cm W.C. The increase can lead to back pressure and eventual shutdown for maintenance.

To prevent this effect of moisture, the temperature of the inlet gases is sensed and if below the setpoint, the controls open a bypass stack, so that the gases are diverted to the atmosphere until the prescribed temperature is reached. Emissions during this time (about an hour) are equal to the loadings of the exhaust gases after only primary treatment in a cyclone or multiclone system, estimated at 400 - 750 mg/scm.[26]

While such bypassing is a part of normal baghouse operation, the quick and accurate sensing of the condition of the inlet gases can minimize the attendant emissions. One plant is testing a Dewcell as an alternative sensor to indicate more precisely when the gases are above the dewpoint and may be sent into the baghouse.

Scrubbers

No data or estimates are available concerning increased emissions under normal startup of scrubbers.

4.2.2 Shut down

Generally the shut down of pollution control devices, when done upon the attendant shut down of the sintering operation itself, does not lead to increased emissions. Of course, when failure of the equipment results in the shutdown of the control device itself while the rest of the sintering operation is kept going, then excessive emission always occur.

Precipitators

When a chamber of a precipitator is deactivated for maintenance or other reasons, frequently rapping is continued after the tower is cut off or reduced. This is done to more effectively clean the plates and thus prepare the system for maintenance. Under such circumstances, increased emissions would be expected from this particular chamber until such time as the air flow itself would be turned off. No data or estimate of additional emissions are available, nor is this particular operation considered of significance with respect to the general control level obtainable by precipitators.

Baghouses

No special abnormal operating conditions leading to increased emissions would be expected from normal shut down of the baghouse.

Scrubbers

No data or estimates are available concerning increased emissions due to normal shut down of these types of control equipment.

4.2.3 Abnormal Operation

Downtime of Control Systems

Downtime of the control system refers to shutdown of the entire gas cleaning facility. One source of total pollution control system failure is catastrophic utility failure, i.e., power loss for a section of the entire plant. Several

plants reported this to occur three times per year to once every five years. A power failure that affects both process and control equipment causes both to shut down and, therefore, the immediate environmental effect is small. If the failure is selective and only the control equipment is affected, then the sinter process will continue to operate subject to interlock protection built into the system. It is conceivable to have a power failure that affects only an ESP without stopping the fans. This kind of upset was not reported by any plant. What plant practice under these conditions would be is not known.

Pump failure and fan failure due to mechanical or electrical problems can likewise shut down the total control system. Most of the plants visited, however, had installed fans and pumps to avoid shutdown due to a problem with a single fan or pump. With installed spares it is likely that at worst the capability to clean or provide draft will be reduced when a failure in one of the control equipment components.

Clarifier rake failure can shut down a scrubber wastewater treatment system. Such failures result from drive motor breakdowns and mechanical failures in the rake drive system. Chunks of material or a buildup of coarse, dense, skirty particulate on the thickener bottom were two things cited as a cause of rake problems. One plant reported that near union labor contract negotiation time there was increased frequency of rake failures due to rocks in the thickener.

Shutdown of the air pollution control portion of the system (scrubbers) may be avoided during a rake failure if the scrubber can be switched from three cycle mode to a once through mode of operation. If no spare thickener capacity exits or no terminal settling basins are in use downstream of the bypass thickener, the increased solids content of the water will be about 6 - 20 g/Mg of steel produced. Many of the plants visited did have terminal settling basins of some sort that would reduce the amount of particulate reaching plant outfall.

Reported frequency of rake failures in the plants visited were between zero and two times per year. The length of time required to repair the equipment and return it to service was reported at one to three days. Both increased

solids and increased water waste blowdown result from this AOC unless production operations are suspended during the repairs. The repair operations require draining the thickener and removal of accumulated solids.

In the area of wastewater treatment backup capability, installed spare pumps and thickeners are a powerful tool to overcome failures in single components. With thickeners, however, an additional alternative may be available through terminal lagoons or settling basins immediately upstream of the plant outfall.

To prevent the failure of thickener rakes, several plants have installed preclassifiers upstream of the thickeners. The commercial forms of preclassifier are varied, but their common purpose is to remove grit and heavy solids from the dirty scrubber water thus affording deposition of such materials in the thickener. One plant covered their thickener with a wire screen to prevent foreign matter (rocks, etc.) from falling into the thickener and fouling the rake.

Precipitators

Downtime of Secondary Systems

Secondary control systems include such units as baghouses to control the pug mill operation and materials handling or emissions from transfer and conveying points as distinguished from the main controls applied to the windbox gases and product handling system. The basic causes of total primary control system failure enumerated in the preceding section are also responsible for total failure of secondary control systems. As was pointed out previously, power failures may be plant wide or local in nature. Where the failure affects the process as well as control equipment the environmental impact is not significant. The comments on duration and frequency in the primary section apply to secondary systems as well.

Fan failures in secondary systems are expected to be more significant environmentally than in a primary system because spare fan capacity does not generally exist. A single fan failure is likely to mean an entire secondary emission control system will shut down without corresponding shutdown of the process system itself. Of course, emissions from secondary sources in sintering are much lower in quantity than those from the main systems.

No data were obtained concerning estimations of the frequency or duration of these AOC's for secondary systems.

Rapping

The successful removal of collected dust by rapping depends on the formation of a coherent dust that will fall in sheets and agglomerate into the hoppers. Within the collected layer, adsorbed gases on the particles provide cohesive forces; interlocking of the particles provides mechanical forces; particle proximity provides Van du Waal's forces; and the preciptator induces electrical forces. The primary consideration in any rapping system is the magnitude of the forces required to dislodge the dust without mechanical damage to the electrodes or support structure, or excessive reentrainment. Because of the height of the plates, it is apparent that some dust will be reentrained as it falls toward the hoppers. This gives rise to a rapping puff, often visible in the plume during the rap. While rapping is a normal part of ESP operation, excessive emissions from rapping are not. To minimize this puff, rapping is done in stages with only a portion of the plates rapped at one time. Various collecting electrode shapes are also used to shield the falling dust from the gas stream, thereby minimizing reentrainment.

The efficiency of rapping, measured in terms of residual dust, is usually improved if the power is removed during the rap. Power-off rapping may be resorted to if normal practice is inadequate. For example, dust would be allowed to build up and then power-off rapped every fifteen minutes, or power-off rapping would be done only once an hour with normal rapping applied during the intervening periods. Of course, that portion of the precipitator that is being rapped with power-off will not be collecting material and stack puffs may result. If parallel units are used, the gas flow can be directed by dampers during rapping so that there is no gas flow through the unit.

Rapper Failure

Collecting plate or wire cleaning mechanisms fail due to age or low reliability. Fialure to remove dust from the electrode surfaces when the plate and wire cleaning systems are in operation may also be due to design deficiencies. Failures of adequately designed equipment can occur either in the control system for the rappers (or vibrators) or in the individual rappers

(or vibrators). The latter type of failure is more common. A control system failure will cause a large group of rappers to fail as opposed to individual rapper failure.

The increase in particulate emissions due to rapper failure may result from grounding a precipitator electrical section (because of dust bridging the wire to plate gap) or reduced collection efficiency in that section when the buildup has not reached the point of bridging the gap. If the section is grounded the additional particulate emissions can be estimated by the methodology presented in the broken wire discussion.

The frequency and duration of rapper and vibrator failures is now known. Frequent inspections will permit early detection of a failure. Inspection is relatively easy for the external rapping and vibrating equipment common to U. S. designed precipitators.

Wire Breakage

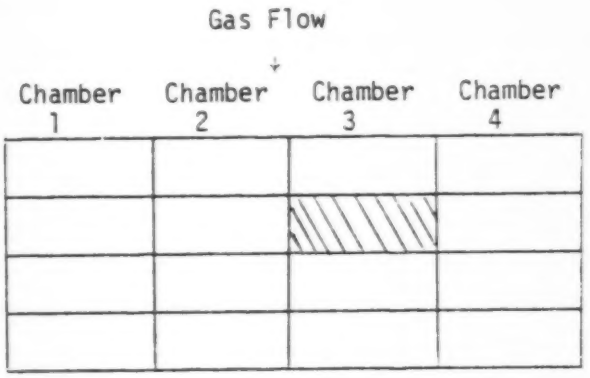
Wire breakage is a problem common to the precipitators using wire discharge electrodes as opposed to rigid fixed charge discharge electrodes. Wire breakage can result from fatigue, corrosion, and electrical stress due to sparking or electrical arcing. When a wire breaks, the broken wire generally contacts one of the adjacent colleciton plates causing the electrical section to short. The transformer-rectifier sets supplying power to the section then trips. With no power in that section of the precipitator, collection ceases. All the sections of the precipitator connected to that transformer-rectifier would be deenergized unless it is possible to disconnect the section with the broken wire and reengerize the remaining sections.

Unless there is a problem with the original alignment of internal components, substandard fabrication of materials, or an unusual event like an excursion with corrosive gases, wire breakage tends to be a random event. With a common random failure rate, larger precipitators will have proportionally more wires failed than smaller precipitators. The data on wire failures do not indicate the size of the precipitators involved, but some variation in failure rates can be attributed to difference in precipitator size. Three plants have reported annual wire breakage of one or more per month, and in other steel plant uses, wire breakage rates up to 200 per year have been reported.

Duration of section outages, which is of course accompanied by increased particulate emissions, is dictated by the plants need and desire to repair broken wires. If there is spare collection capacity, there is not need to shut down a precipitator or a precipitator chamber to repair it immediately. Several breakages may accumulate before a shutdown is necessary. However, most shops have a weekly turndown for maintenance and broken wires can be replaced at this time.

Cutting out broken wires as opposed to replacement does not cause performance to significantly deteriorate unless the wires are adjacent.

The increase in particulate emissions with a section out of service due to wire breakage can be calculated given the operating efficiency of the precipitator fully energized, total collection surface area, gas flow, and the area of collection surface out of service. Following is an example of the calculation.



Given: Four chamber, four field precipitator
Operating efficiency, η, = 98%, fully energized
Gas flowrate, Q, = 8496 m^3/min (300,000 acfm)
Total collection surface area, A, = 12,115 m^2 (130,400 ft^2)
Area not in service, 757 m^2 (8150 ft^2, 1/16)

The efficiency of chamber 3 with one field out of service is 94.7 percent obtained by:

1) Evaluate w = migration velocity using the given operating efficiency of 98 percent:

$$w = -Q/A \ln(1 - \text{fr eff}) = \frac{300,000}{130,400} \ln (0.02) = 9.0$$

2) Using this value of w, evaluate efficiency of the chamber with one field out of service:

$$\text{Efficiency} = 100(1 - e^{-(\frac{24450}{75000} \times 9)}) = 94.7$$

The average efficiency, with the one field out of service is 97.2.

$$\eta, \text{ average} = \frac{(3 \times 98) + 94.7}{4} = 97.2$$

Particulate emissions should increase by a factor of 1.4

100 - 97.2/100 - 98 = 1.4 times the normal emissions.

This technique can be applied to precipitators with more than one field out of service in several chambers equally well.

Where wire breakage rates are high the alignment of electrodes should be checked to be sure erection tolerances are being met. Sometimes when mass failure occurs the material of construction is found to be inferior.

If high spark rates in a particular section are observed with a high incidence of breakage and yet the alignment is satisfactory, shrouded wires should be installed in place of standard discharge wires. The shrouded wires have protective sheathes at the top and/or bottom of the wire to decrease electrical stresses caused by sparking or arcing. Use of shrouded electrodes in some cases has decreased the frequency of wire failures by a factor of five.

Heavy sparking may also be caused by the inability of some older type transformer-rectifiers to properly modulate current input. This problem may be eased by use of solid state controls with better controlling characteristics.

Dust Removal System Breakdown

This AOC is produced by a myriad of causes. Among them are broken screw conveyor shafts, plugged dust valves, dust bridging or sticking in the hoppers, hopper heater failures, and hopper vibrator failures. Problems with dust removal are frequent and common to all plants using dry collection systems.

Filaure of dust storage and removal equipment leads to full hoppers. When the dust level in the hoppers reaches the bottom of the discharge wires or the steadying frame that aligns them, two things can occur. The preferable occurrence is to have the TR set trip due to undervoltage (caused by shorting through the dust to ground). Collection will stop in the electrical section above the effected hopper and in any other section energized by the same TR set, thus preventing any damage to the internal components. If the under-voltage trip protection does not work or does not exist, the dust level will continue to rise and begin lifting discharge electrodes and their steadying frame. Permanent damage to the electrode system may be done in this case. Repairs to the steadying frame and wires require a precipitator shudown more lengthy and costly than the usual repairs required by the dust removal system. Therefore, it is a better choice to shutdown the affected collecting area for repairs to the dust removal equipment.

Sometimes secondary problems develop from efforts to solve the primary problems. One of the methods chosen to breakup dust plugs in the double flapper type dust valves is to strike the valve casings with a hammer. While the dust plug may be broken the valve casing is often bent thus preventing a good seal between the flapper valve and the valve seat. On negative pressure installations, this allows dust to be drawn back into the precipitator along with cold air. The cold air may produce corrosion damage to the collecting plates and some of the dust bypasses the precipitator going uncollected. Because dust valves produce many sticking or plugging problems, some operators remove them. This solution is only satisfactory if the hoppers are always left with enough dust at the bottom to act as a seal. If not, the same air inleakage problem will occur.

Sprays Plugged or Corroded

Moisture may be added to the exhaust gases as a conditioning agent, or it may be present because of the collection of vapors from spraying hot fines. Without moisture, the particulate resistivity remains high and the collection efficiency is reduced. A lack of conditioning may be evident as more opaque visible emissions from the stack.

Most spray systems are fed by recycled water, so that common cause of spray plugging is solids buildup in the nozzle. The reduced flow area reduces the amount of water atomized and consequently evaporated. Corrosion is also a cause of problems. Atomization may be impaired by corrosion damage to the nozzle, even though the quantity discharged is normal.

The frequency of this AOC is highly variable. In a plant with a regularly scheduled downturn, say once per week, an inspection and/or change is possible often enough to avoid the problem.

The duration of the problem is as long as it takes to repair or replace the nozzles. With no maintenance, emissions will continue to increase. Some of the plants visited indicated that repair is possible within an hour or two after discovery of the problem.

The quantitative increase in particulate emissions during this AOC cannot be readily calculated. The fact that the degree of induced conditioning effects is so variable is the primary reason.

To reduce the frequency of this AOC regularly scheduled inspections of the spray systems should be made. The schedule must be more frequent than plugging or corroding frequency to be an effective preventative maintenance program.

Transformer-Rectifier Set Failure

Transformer-rectifier (TR) sets are the power supplies for the electrical sections in the ESP. When a TR set fails, the section energized by that TR set is out of service for as long as it takes to replace the faulty set or until a temporary connection is made into an adjacent set. Set failures are typically caused by age and/or overheating. The failure may occur in either of two portions: the transformer or the rectifier and control portion. The control portion of the unit is the more frequent scene of the failures. The newer solid state controls are particularly vulnerable to damage or shorting from overheating.

The estimate frequency of TR set failures is from once to twice a year. A failure that occurs in the printed circuit card is readily repaired. A failure that occurs in the transformer may take a month to obtain a replacement and install it. The range of duration of this type of failure is thus two hours to one month. Increased particulate emissions can be calculated using the same methodology presented in the wire breakage discussion secton.

If a severe period of overheating (e.g., in the summer) is anticipated, the room housing the ESP controls can be air conditioned to reduce failures. The effects of a failure may be minimized by temporarily connecting the failed electrical section to a TR set feeding an adjacent collecting area. The adjacent section may suffer some performance decrease, but the net effect will improve overall ESP performance under the conditions. Because of the time involved in making such a connection, it is probably only justified when replacement is expected to take more than several days.

Insulator Failures

Insulators that support the discharge electrode system are subject to failure from cracking or tracking. Failures are caused primarily by dust or moisture on the insulator surface that allows current to track across the insulator and short out a precipitator electrical section. Cracking may be produced by either mechanical or electrical stress.

The failure of insulators produce the same effect as broken wires or transformer failures. The increase in particulate emission can be calculated by the same methodology presented in the broken wire discussion.

Insulator failures are not a frequent problem according to a survey done in the electric utility industry.[36] No data on frequency of occurrence or duration were reported during the plant visits.

Insulator failures are best prevented by frequent inspections of the insulator housing pressurizing fan and filter or inspection and cleaning of the insulators themselves where the fan and filter system are not used. For a typical steel plant environment, a pressurizing fan and filter system to supply air to the insulator housing is good design practice. This type of inspection is a maintenance item that can be done on the weekly downturn for repairs and adjustment.

ESP Maintenance

Most successfully controlled sinter plants shut down one shift (turn) per week. In this 8-10 hour period, planned maintenance is performed. ESP's should be checked daily: vibrators, transformers, and voltages. Insulators need cleaning weekly, and at that time transformers can be inspected for oil leaks.

Fabric Filters

Torn or punctured bags allow unfiltered gases to pass. Extreme conditions can be detected at the control panel (pressure drop) and by visible emissions from the baghouse, or under planned inspection.

The frequency depends upon how old the bags are relative to their service life. Good bags have been lasting 18 - 24 months. Near the end of bag life cycles, plants have counted up to 150 broken bags out of 7200 on each two-week inspection. As bags near the end of their use cycle, failures persist for up to four months unless a complete replacement of old bags is carried out at one time. Best practice includes planned replacement before the critical failure rate occurs.

Isolation of the bag compartment and replacement of the bags is the proper corrective action. Replacement labor may run 1 to 3 hours per bag.

Sudden changes in baghouse operating pressure can usually be traced to a malfunction.

1. If torn or punctured bags are the cause, there will be dust in the clean air plenum where bags need replacement.
2. If there is loss of compressed air pressure required for the cleaning cycle, the pilot valves should be removed and cleaned.
3. If the air-to-cloth ratio is too high, it is necessary to check the fan speed and air flow to correct (design) values.

Where a baghouse has been used on windbox gases, the amount of oil-bearing feed has been limited to a low percent of the total to prevent either clogging of the bags, or chemical reactivity in the collected particulate material. Excessive hydrocarbon in the collected dust can contribute to ignition of the collected dust, and its fusion and bridging in the collection hoppers.

Baghouse Maintenance

Exhibit 1 shows an example maintenance guide for a baghouse serving a sinter plant.[27] Most well-operating baghouses have a spare compartment so that cleaning may be performed without losing gas handling capacity. If one compartment is tied up for repairs when the second is removed for cleaning, there would be two out of service and a consequent loss in capacity.

Scrubbers

High velocity inertial type scrubbers can show a sudden loss in efficiency, which usually is apparent from the attendant change to a highly visible plume. The first particles to penetrate the scrubbers if there is low pressure drop for example due to reduced gas flow, will be the finest (smallest) ones. These will usually form an opaque cloud.

Adjustment of the scrubber throat to restore the pressure drop is the corrective action where variable-throat scrubbers are used. Most sinter plant scrubbers have variable-throats. If no such adjustment is possible, then provision should be made for varying the liquid flow in order to maintain the pressure drop.

To determine how much pressure drop might be controlled by changing water flow, data for pilot scrubbers by Eberhardt and Graham were analyzed to obtain the following relationship:

$$\Delta p, \text{ in. of water} = -10 + 1.7\ (1000 \text{ cfm gas/ft}^2 \text{ of throat area}) + 0.96\ (\text{gal water/1000 cfm gas}).$$

Thus, an increase of one gal water/1000 cfm gas should raise the ΔP 0.96 inch of water.[42]

EXHIBIT 1

SINTER PLANT FABRIC FILTER (BAGHOUSE) MAINTENANCE AND TROUBLESHOOTING GUIDE

REQUIRED MAINTENANCE - OPERATORS AND OTHER PERSONNEL

DAILY

1. Inspect all screw conveyors and conveyor drive belts for seepage and wear. Listen for unusual sounds. (Operators)
2. Make sure main control room, walkways, and conveyor housings are clean of all dust and debris. Be sure pressurizing fan is operating and keep doors closed.

WEEKLY

1. Lubricate screw conveyors until slight lubricant seepage (Operators).
2. Lubricate shake shafts. (Operators)
3. Inspect fan motor bearings. (Electrical)
4. Inspect fan damper bearings. (Operators)
5. Inspect hoppers by removing some bags from tube-sheet and looking down into hoppers, then reinserting bags. (Operators)
6. Inspect bags for proper seating, tension holes, or burns. (Operators)
7. Inspect compartments for excess dust, water, etc. (Operators)
8. Inspect control room pressurizing fan filter and housing. (Operators)
9. Inspect double-dump valve cams and cam followers. (Operators)

MONTHLY

1. Lubricate fan bearings every 30 days with 2 1/4 to 2 1/2 oz. of grease. (Mechanical)
2. Lubricate bullseye damper shafts. (See Figure 4 for location) (Operators)
3. Inspect shaker assembly for V-belt tension, etc. (Mechanical)
4. Lubricate double-dump valve gear box. (Operators)

EXHIBIT 1 (cont'd.)

5. Inspect ID fan, fan blades, internal housing, for wear or other damage. (Mechanical)

EVERY 6 MONTHS

1. Check inlet damper lubrication level; lubricate when necessary. (Operators)
2. Inspect inlet manifold and ductwork for dust build-up and leaks. (Operators)
3. Inspect outlet manifold and ductwork for dust build-up and leaks. (Operators)
4. Inspect screw conveyors internally for damage and proper operation. (Mechanical)

AS NEEDED

1. Lubricate access door latch bearings. (Operators)
2. Clean hoppers in event of a blocked hopper of malfunctioning screw conveyor. (Operators)

Where scrubbers show incomplete throat coverage with liquid, there may be insufficient liquid injection points, leaving spaces where unscrubbed gases can pass. The use of liquid weirs within the venturi, with the gas atomizing the liquid before the throat may help avoid liquid distribution problems. No data or estimates of the increased emissions from these causes are available.

Where low pressure drop is caused from an eroded or poorly set orifice or low water flow due to low pump delivery or plugged nozzles, preventive maintenance is required. These AOC's can yield increased emissions of 2.5 - 10 g/kg of product.

Excessive water emission from a scrubber may indicate an eroded or damaged demister. The effect is an increase in corrosion of the system and emissions of (usually) acidic dirty water. Repairs are the remedy. While no data are available, estimates could be made of the increased emissions in specific cases.

Sprays Corroded or Plugged

Sprays located in the venturi are the most frequent cause of performance problems. Solids accumulation in particular is reported as a major cause. After a year or two of operation, the best material of construction to avoid corrosion damage will likely have been chosen and installed. However, excursions in the system pH could occur in some plants causing some unexpected corrosion problems. The most typical situation is perhaps an alkaline condition resulting from carryover of the fluxing agents added to the sinter burden. Because of alkaline conditions, scaling is an important factor in this AOC.

The result of improper atomization and/or insufficient water flow to the scrubber is reduced efficiency of particulate collection. In conventional venturi scrubbers with high pressure drop, scrubber efficiency may not decrease with decreasing liquid gas ratio (L/G) over a range of L/G values. Some work done in West Germany has shown that scrubbing efficiency begins to decrease when the L/G drops below 0.6 ℓ/scm (approximately 5 g/1000 scf).[37] The exact quantity of relationship between decreasing water rate and scrubbing efficiency may be available from the scrubber manufacturer.

No direct data on frequency of plugging and/or corrosion of sprays were obtained. Related to findings on sprays for precipitators, the highest would be three times per week. A low estimate would be six times per year. Estimated time to repair the venturi sprays would be up to 8 hours after identifying the problem.

Where spray damage is identified as a corrosion problem, special alloys must be considered for use. In a recycled water system care must be taken with respect to chloride buildup. High chloride concentration will attack Type 316 ELC stainless steel, so higher alloys such as Inconel 625 or Hastalloy C may be necessary, even though much more expensive than stainless steel. Since maintenance can be provided each week during the downturn, the optimum choice may be partly material selection and partly chemical control of corrosion. Since nozzle losses in sinter plants are caused mostly by abrasion rather than corrosion, the higher alloys will not show much improvement in life over Type 316 ELC stainless steel.

Where plugging, not corrosion, is the problem, improvement of the water supply is important or regular maintenance during the downturn period will be required. Certain scrubber designs include automatic cleaning devices to clean the nozzles. These devices may be effective, but apparently work well only with some minimum water quality, say 100 ppm maximum suspended solids.

Solids in the recycled water may be reduced by the reduced by the use of polyelectrolytes to improve settling characteristics. If the plugging is due to scaling, the use of scale inhibitors and pH control canbe considered.

Plugged or Corroded Pipes

The cause of this AOC is scaling resulting from contaminants carried into the recyle water. The discussion in the previous paragraphs on causes and solutions to the problems generally apply. Piping is considered less expendable than nozzles, however, and so more resistant materials of construction may be chosen. Rubber lining is used to avoid corrosion losses as an alternative to higher grade alloy steel. One plant reported plugged or unbalanced water system problems five times over a 10 month period. No duration was reported.

The consequences of plugged pipes include reduced scrubber efficiency due to low water flow, and overflow of tanks or thickeners in the recycle water system leading to spills to the sewer. Corroded pipes can lead to spills to the sewer and inadequate scrubber water flow also.

Corroded Pump Impellers, Pump Failure

In addition to the problems and solutions presented in the previous two topics, pum failure can be caused by abrasive wear to the impellers and motor failures. The resulting low water flow may reduce the scrubber efficiency. Most plants have installed spare pumps so that if one fails another can be brought into service.

Without a spare available, low flow conditions could last two to eight hours before repairs are completed. No data or estimates are available concerning the frequency with which this problem has occurred in sinter plants.

Sensors to detect low water flow and the pump operating status are keys to early warning of an impending problem. Rubber lined pumps can be used to provide corrosion and abrasion protection. Alternatively, pH control and corrosion inhibitors can be used to avoid corrosion damage. If the water system has not preclassifier such a device may be installed to reduce abrasive wear. If a preclassifer does exist its adequacy and location relative to the system should be investigated.

Plugged or Failed Demister

Scrubber systems have some sort of device to separate entrained water from the gas stream. This prevents water droplets containing particulate matter f.om being carried out the stack, adding materially to the emission rate. It also prevents chemical damage due to the acidity or alkalinity of the water.

The entrained separator or demister is usually some type of baffle device that presents an impingement surface to the gas stream or a cyclonic type of separator. Solids can build up in these devices. The result is reduced flow area and consequently increased pressure drop. In a system with fixed fan

capability, the static pressure developed must be used either upstream or downstream of the fan. If a mist eliminator pressure drop increases at the normal system flow rate, then the scrubber pressure drop must increase by a corresponding amount. Alternatively a total gas flow rate may be decreased and the scrubber pressure drop maintained. In the latter case, fugitive emissions develop at the hood, in the former case the scrubber efficiency decreases.

The frequency and duration of this AOC are unknown. The increase in particulate emissions might be calculated if the scrubber pressure drop decreases. The scrubber manufacturer usually has developed a curve of outlet concentration versus pressure drop for this purpose.

Pressure drop across the demister can be monitored within an alarm to warm of a developing problem. Periodic washing of the demister will prevent this AOC, and this can be done at the regular sinter plant downturn each week for maintenance.

Drum Filter Failure

Underflow from the thickener(s) in the recycle system is often dewatered by vacuum filtration either by rotary drum or disc-type. The vacuum system required in these installations are reported to be high maintenance items. A number of plants have found it necessary to retrofit spare filters as a result. One problem is apparently related to solids spillover into the vacuum pump resulting in abrasive wear.

With no spare drum filter available if repairs can be made within an hour or two the AOC will not necessarily produce increased solids in the effluent. There is some solids surge capacity in a thickener. Longer repair means either solids spillover or all the underflow must be transported to the disposal site. The underflow gives a much larger volume to dispose of than the dewatered sludge. Depending on the disposal site liquid runoff could be a problem.

No data on frequency of occurrence were found, but the general impression from the operators was frequently with onlg enough repair times to justify a spare drum filter. Spare filter capacity then is a primary means of avoiding the AOC.

Acid Cleaning Scrubber Components

Acid washing of scrubber system components may be used periodically to remove accumulated scale deposits. Particularly the quencher, the venturi, the entrainment separator, the gas cooling tower, pumps, pipes, and nozzles are susceptible to scale deposits that impair scrubber system operation. The acid wash itself is not an AOC if precautions are taken to prevent spilling to the sewer without neutralizing.

Review of NPDES data shows that spills do occur. Data from one plant showed low pH discharges (< 6.0) for periods of 10 minutes to 3 hours due to acid washing of various plant scrubbing systems, including BOP furnaces and blast furnaces. Over a period of 18 months, this AOC occurred twice for the BOP furnace system and four times for the blast furnace. Prevention of this AOC is possible by proper planning. Piping, pumps, and tanks can be arranged to capture the used acid, settle suspended solids, and neutralize the acid before discharge.

Control Process Modifications

One plant, which used a baghouse on the windbox gases, found that by recycling product handling dusts to the windboxes, the plugging of the windbox fabric filters was alleviated. The hard particles seemed to condition the windbox dusts for better collection by baghouse.[33]

5.0 TABULATED SUMMARY OF AOC

Table 5.1 summarizes the AOC's described herein. The identification of an AOC carries no implication whatsoever concerning liability for resulting air or water pollution. Liability for an AOC can only be determined by the enforcement officer responsible for a given set of regulations (NSPS, SIP) or permit requirements (NPDES, special conditions, etc.).

TABLE 5.1. SINTER PLANT ABNORMAL OPERATING CONDITIONS

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
PROCESS RELATED -- STARTUP							
Condensation in ductowork	Cold duct	Corrosion, changes in dust character	None practical	Potentially each startup, ≥ 1/2 wk	1 hour	In practice, ESP or Baghouse bypassed increased emissions 450-700 mg/scm	26
Hearth layer not formed properly	Improper startup	Excessive dust loadings, windbox gases	Proper startup, shut down till hearth layer problem is corrected	Varies	5 min	Excessive emissions > 50 kg/hr	43
PROCESS RELATED -- SHUT DOWN							
Burn through if fan continues to run	Strand stopped, burden ignited	Exhuast gases cool down	Stop fan	Varies	Varies	Increased emissions opacity	Est.
PROCESS RELATED -- ABNORMAL OPERATING CONDITIONS							
Baghouse accidentally shut down	Error by service personnel	None	Avoid error	Seldom	35 min	Increased emissions est. 400 kg/hr	43
Excess air leakage	Failure of seals, holes in sinter burden	Holes in ducts, overloads fans and dust collectors	Maintain seals, adjust feed mix, patch holes, mtn. of flapper valves	Varies ≥ 3/yr	Depends on mtn.	Increased load on emissions controls. Increased emissions	35
Grate bar distortion	Heat from process, failure of hearth	Excess dust into windbox	Use sp. alloys, hearth layer	Varies	Depends on mtn.	Increased emissions	26
Excess loading or windbox or discharge exhaust	Poor sinter quality too much fine material, poor moisture control or feed control, or ignition	Poor quality, lower yield	Good practice and control	Varies	Persistent until corrected	Increased emissions	26

TABLE 5.1. (cont'd)

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
Screening station equipment fails	Breakdown	Stops production, or product handled by temporary procedure w.o. controls	Preventive mtn.; shut down sinter plant	Varies	Several days to hand screen accumulated product	Severe dust problems and uncontrolled emissions	40
Increased particulate resistivity	Increase in MgO, CaO in dust due to increased target B/A ratio	Lower temp. of sintering, changes in dust characteristics	Reduce basicity of sinter; adopt alternative control equipment	Varies	Persistent	Increased emissions if ESP used	26,11
Inadequate mixing of burden	Failure of equip., e.g., pug mill water pump	Non-uniform sintering	Shut down, adjust, repair	Varies, 0-4/yr	Until corrected, 10 hours	Increased emissions	26,40
Inaccurate burden mix proportioning	Failure of feeder controls	Shut down, short time	Adjust, repair	Varies to several times per week	1-2 hours	None if fans, pumps are stopped	26
Hood picks up chunks of sinter	Hood too close to process equipment	Abrasion in fan housing, fan rotor	Reset hood	Persistent	Till corrected	None if process shut down for mtn.	34
Use of petroleum coke for fuel	Shortage of coke breeze	Smoke emissions from ESP	Use correct fuel, modify ESP, or convert scrubber	Varies	$\geq$ 1 hour	Increased hydrocarbon emissions	35
			CONTROL EQUIPMENT RELATED -- STARTUP				
ESP							
Low temp. gases	Cold startup	Not powered till gas is hot	Put heaters on insulators, defog before start	Entire unit 1/wk Single chamber to 1/wk	1 hour	Increased emissions 450-700 mg/scm	26
Settled dust reentrainment	Change in damper	Higher inlet loading	None practical	1/yr - > 1/wk	5 min	Increased emissions	35
Dust overload on conveyor belt	Hoppers all dump dust at once	Fugitive emissions	Sequence dumping of hoppers	Periodic, repetitive	Cyclic	Persistent additional fugitive emissions	40

TABLE 5.1. (cont'd)

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
			CONTROL EQUIPMENT RELATED -- SHUT DOWN				
Dust overload on conveyor belt	Hoppers all dump dust at once	Fugitive emissions	Sequence dumping of hoppers	Periodic,	0 - ≥ 1/wk	Additional fugitive emissions	26
Settled dust re-entrainment	Change in damper setting	Higher inlet loading	None practical	≥ 1/wk	5 min	Increased emissions	40
Low temp. gases	Cold startup	Not powered till gas is hot	Put heaters on insulators, defog before start	Varies, 1/wk	1 hour	Increased emissions 450-700 mg/scm	26
Low temp. inlet gas	Cold start, loss of ignition	Plugs, blinds bags	Bypass baghouse	Once-twice/wk	1 hour	Increased emissions 400-700 mg/scm	26,40
ESP shut down ahead of process	Operating practice avoid deposit of condensate	Control bypassed	Alternate control, revise shut down	Each shut down (≥ 1/wk)	1 hour	Raw emissions to air 450-700 mg/kg	34,26
			CONTROL EQUIPMENT RELATED -- ABNORMAL OPERATING CONDITIONS				
ESP							
Transformer or rectifier abnormal oper. cond.	Poor operating practice or inadequate design	Reduced efficiency	Repair or replace	Varies	Varies, till repaired	Increased emissions 0.05-1 gm/kg product	26
Screw conveyor breakdown	Foreign material	Shut down (partial shut down) of control equipment	Repair, replace	Varies to 7/yr	1-4 hours	Efficiency loss 30-100% emissions increase 450-700 mg/scm	26,35
Dust bridging in hoppers	Inadequate dust discharge design, or condensation or cooling of dust	Dust buildup to lower high tension stabilizing frame, leading to shut down	Impact rapper, or compressed air rapper, heat trace and insulate	Varies	Varies	Increased emissions 450-700 mg/scm	26,40

TABLE 5.1. (cont'd)

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
Loss of chamber	Failure of insulator wear, erosion	Loss of efficiency	Repair, activate spare chamber	Varies, 2/yr	Varies, 1-4 hours to 2 days	Partial loss of eff. emissions > 120 gm/kg	26,35, 40
High resistivity particulate	Change in process feed composition	Reduced efficiency	Additional precipitators, change of feed	Frequent or persistent	Continuous when occuring	Substantially increased emissions 1.5-7.5 gm/kg	Est.
Broken or shorted electrodes (15 or 20 before shut down)	Fatigue failure	Reduced efficiency	Repair	Variable	Variable, 3 hrs - 2 days	Increased emissions 0.05-1 gm/kg	Est., 40
Malfunction of rappers & heaters	Poor maintenance	Reduced efficiency plates don't clean	Repair	Varies, depends on dust and ESP	Varies, gradual decline in eff.	Increased emissions 0.05-1 gm/kg	Est.
Reduced voltage	ID fan malfunctions with ESP interlock	Lower efficiency	Maintenance of fan	Once or more/month	Varies, 1-2 days	Increased emission est. to 450 mg/scm	26
Fan failure	Miscellaneous causes	Loss of control	Adequate standby and mtn. or shut down sinter plant	Infrequent, < 5/yr	Varies, fan repair 5-97 hours	None if strand shuts down	26,35
Power failure	Miscellaneous causes	Loss of control	Shut down source	Infrequent	Varies	Some increased emissions	26
Excessively open hoods	Inadequate mtn. or design	Fugitive emissions at hoods	Close hoods	Varies	Varies	Increased emissions 0.05-1 gm/kg	Est.
Eroded fan blades	Infrequent mtn.	Fugitive emissions	Do not use hollow plate, use floor-plate tread on blades. Repair fan	Varies	Varies with mtn.	Increased emissions depending on individual situation	26

TABLE 5.1. (cont'd)

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
			CONTROL EQUIPMENT RELATED -- STARTUP				
Baghouse							
Low temp. inlet gas	Cold start, loss of ignition	Plugs, blinds bags	Bypass baghouse	Once-twice/wk	1 hour	Increased emissions 450-700 mg/scm + opacity	26,40
			CONTROL EQUIPMENT RELATED -- SHUT DOWN				
Baghouse shut down (bypassed) ahead of process	Desire to avoid cooler gases plugging bags	Control bypassed	Alternative control	Each shut down ($\geq$ 1/wk)	1 hour	Raw emissions to air 450-700 mg/kg	34
			CONTROL EQUIPMENT RELATED -- ABNORMAL OPERATING CONDITIONS				
Baghouse							
Excessive oil in burden mix	Poor balance of raw materials	Blue hydrocarbon plume	Planned raw material consumption limit on oil content of feed	Varies	Persistent	Increased emissions 0.1 to 0175 gm/kg	Est.
Excessive visible emissions	Torn bags	Change in compartment ΔP	Preventive mtn.	Constant when occuring f(bag age) at near end of life, up 150 bags/two wk inspection	Till repaired, 1-7 days	Increased emissions 300 mg/scm	40
Fire in baghouse ducts (or windbox)	Ignition of HC in dusts	Damage to system	Limit HC in feed, dump hoppers continuously	Varies	Until brought under control	Increased emissions	40
Excessively open hoods	Inadequate mtn. or design	Fugitive emissions at hoods	Close hoods	Varies	Varies	Increased emissions 0.05-1 gm/kg	Est.
Eroded fan blades	Infrequent mtn.	Fugitive emissions at hoods	Repair fan	Varies	Varies with mtn.	Increased emissions depending on individual situation	26

TABLE 5.1. (cont'd)

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
Power failure	Miscellaneous causes	Loss of control	Shut down source	Infrequent	Variable	Some increased emissions	26
Fan failure	Miscellaneous causes	Loss of control	Adequate standby and mtn.	Infrequent < 6/yr	Variable; fan repair 5-97 hours	Increased emissions 450-700 gm/kg	26,35
Duct abrasion	Abrasive dust	Infiltration of air	Lime with high alumina ceramic	Varies	Till repaired	Possible increased emissions	26
Shut down for major repairs	Postponement of mtn. due to need to modify system under contract	Baghouse out of service	None, but shut down of sinter plant during reinstallation of control	No data. Should be one time occurrence	5 wks	Increased emissions 450-700 gm/kg	26,35
Plugged bags	Moisture and/or oil vapors in gas	Fugitive emissions discharge end of process	Eliminate or reduce moisture or oil vapors in gas	Varies	Varies up to time better bags are (7 mos) if this is the cause	Increased emissions severity depends on situation	33
Failure of dust removal system	Poor mtn.	Loss of control	Proper mtn.	1-3/yr	Variable 3-10 hours	Fugitive emissions	35
SCRUBBER							
Fan failure	Miscellaneous causes	Loss of control	Adequate standby & mtn. or shut down sinter plant	Infrequent ≤ 5/yr	Variable fan repair 5-97 hours	Increased emissions 450-700 mg/kg	26,35
Power failure	Miscellaneous causes	Loss of control	Shut down source	Infrequent	Variable	Some increased emissions	26
Eroded fan blades	Wrong materials of construction	Fugitive emissions	Repair fan	Varies	Varies with mtn.	Increased emissions depends on individual situation	26
Excessively open hoods	Inadequate mtn. or design	Fugitive emissions at hoods	Close hoods	Varies	Varies	Increased emission 0.1-1 gm/kg	Est.
Excessive oil in burden mix	Poor balance of raw materials	Blue hydrocarbon plume	Planned raw material consumption limit on oil content of feed	Varies	Persistent	Increased emissions 0.1 to 0.75 gm/kg	Est.

TABLE 5.1. (cont'd)

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
Low water flow	Poor mtn. pump failure	Reduced efficiency	Repair pump	1-6/yr	0.1-1 day	Increased emissions 0.1-1 gm/kg, 80% loss efficiency	35
Demister failure	Plugging, air flow too high, corrosion	Mists escape collection	Mtn. repair, adopt better equipment	Varies 1/yr	Until corrected 1-3 days	Increased emissions 0.5-1 gm/kg	Est.
Plugged, eroded sprays and/or water supply	Solids buildup, eroded or poorly set orifice, corrosion	Reduced efficiency	Preventive mtn., adjust, control water chemistry, clean scrubber	Varies 1-4/month	Until corrected 1-8 hours	Increased emissions 400-500 mg/scm	35
Erosion of rubber lining of scrubber	Abrasion	Plugging, interruption	Rebuild scrubber, use refractory lining, use plastic pipes, cement grout (SiO_2, Al_2O_3 aggregate w/epoxy resin) behind refractory lining	Varies 1-6/yr	Till repaired 3-30 days	Increased emissions	40
Excessive overflow, recirculation water	Poor control, line blockage in settling basin	None	Better control, clear lines	once/month	1 day	SS exceeded daily limit	44
Low gas flow	Throttled fan to avoid fan imbalance	Reduce ΔP on scrubber	Mtn. repair, clean fan	Varies $\leq$ 5/yr	Until repaired 5-97 hours	Increased HC emissions, some increase in particulates	35
Low pH	Control excursion, faulty signal from pH controls	None	Mtn. controls, better, more durable pH meter	Once/month	Unknown	Eff. exceeded daily limit	35
Water carryover from demister	Inadequate disengaging height	Demister plugged w/ $CaSO_4$, shut down, poor mtn. practice	Redesign; larger disengage height, Chevron demister of 304 stainless steel	Varies, if mtn. related 1/yr	Until corrected 1-3 days if mtn. related	Increased emissions	40

TABLE 5.1. (cont'd)

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
WESP[1]							
Power failure	Miscellaneous causes	Loss of control	Shut down source	Infrequent	Variable	Some increased emissions	26
Fan failure	Miscellaneous causes	Loss of control	Adequate standby & mtn. or shut down sinter plant	Infrequent < 5/yr	Variable, fan repair 5-97 hours	Increased emissions 450-700 gm/kg	26,35
Breakdown	Corrosion	Shut down	Control of recirculating water, better materials of construction, pH control	Varies	Till repaired	Increased emissions	40
SS too high in wastewater	Drain water from ESP cleaning entered sewer directly due to broken dam	No affect on control process	Drain water to treatment plant	Up to twice/month	One day	SS exceeded daily limit	44
WASTEWATER TREATMENT							
Clarifier failure	Rake failure, sludge pipe plugged, sludge pump failed	Recirculated water is turbid	Repair, better mtn.	1/yr	1-5 days	Increased solids in blowdown 0.222-660 gm/kg	40
High level in sump	Level control of pump failure	Overflow of wastewater	Repair, mtn.	1-6/yr	0.5-1 day	Increased pollution 0.22-2.2 gm/kg	Est.
Low sludge density	Broken dewatering equipment	Recirculated water is turbid	Repair, mtn.	1/yr	1-3 days	Increased solids in blowdown, decreased sludge density, 0.05-1.5 gm/kg	Est.
Poor performance	Corrosion of internal elements	Increased mtn. & increased emissions	Preventive mtn., pH adjustment	Varies	Persistent until corrected	Increased emissions	26
Change in composition of wastewater	Change of gas composition	Possible corrosion	Modify process operation or treatment of water	Varies	Varies	Can cause increased discharge of dissolved solids (e.g., heavy metals)	26

TABLE 5.1. (cont'd)

Abnormal Operating Condition	Cause	Effect on Process	Corrective Action	Frequency	Duration	Environmental Effects	Reference
Inadequate flocculation	Chemical addition failure	Recirculated water is turbid	Repair, better mtn.	Unknown	Unknown	Increased solids in blowdown, decreased sludge density	26
Feed mix change		No effect on scrubber	Modify feed mix	Varies	Varies	Increased discharge dissolved solids	26
GRAVEL BED FILTER							
Poor dust removal from gravel	Adherence to garnet media	Clogging	Use cracked steel shot as gravel	Till corrected	Persistent	If bed bypassed, increased emissions	39
Malfunction of back wash valves	Design deficiency	Unit plugs	Redesign valves	Persistent	Till corrected	Increased emissions	

[1] No full-scale WESP is now in operation. Units are expected in two years. Limited experience means limited data on AOC's at this time.

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